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Memoirs of the Geological Survey, Scotland

THE GEOLOGY
OF THE
GLASGOW DISTRICT

(Glasgow District Map, including Parts of Sheets 30, 31,
22 and 23.)

BY

The late C. T. CLOUGH, M.A., F.G.S.; L. W. HINXMAN, B.A., F.R.S.E.;
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AND A Chapter on the Palæontology by

G. W. LEE. D.Sc., F.R.S.E.

REVISED EDITION

BY

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Published by Order of the Lords Commissioners of His Majesty's Treasury.

Edinburgh
Printed under the Authority of His Majesty's Stationery Office.

And to be purchased from
E. STANFORD, Ltd., 12, 13 and 14 Long Acre, London, W.C.2;
W. & A. K. JOHNSTON, Ltd., 4 George Street, Edinburgh;
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PREFACE TO FIRST EDITION.

This memoir describes the geology of the Glasgow District Map, which comprises an area of about 230 square miles, extending from the Campsie Fells and the village of Killearn in the north to the Cathkin Hills in the south, and from Renfrew and Barrhead in the west to Bothwell and Gartcosh in the east. This map, which includes portions of Sheets 30, 31, 22, and 23, has been specially prepared for economic and educational purposes with Glasgow as the centre.

The geology of those portions of the Glasgow District Map that lie within Sheets 22, 23, and 31 was described in the Explanations of these Sheets published in 1872, 1873, and 1879 respectively. No descriptive memoir of the part included in Sheet 30 was issued.

The results of the revision of the Carboniferous districts with the associated igneous rocks, which was begun in 1904, and continued at intervals till 1909 by Messrs. Peach, Clough, Hinxman, Grant Wilson, Crampton, Wright, Bailey, Anderson, Carruthers, and Grabham, are incorporated in this memoir. All these officers, except Dr. Peach, who retired from the service in 1905, have furnished descriptions of their respective areas.

The northern portion of the map, including the lower of part Strathblane, and almost the whole of the volcanic plateau of the Campsie Fells, was revised by Mr. Bailey ; the ground between Strathblane and the eastern end of the Kilpatrick Hills by Mr. Grabham. To Dr. Crampton was assigned the Kelvin valley from Milngavie to the edge of the Sheet near Kilsyth, and the southern slopes of the Campsie Fells. Mr. Carruthers examined the Bearsden district, and the western suburbs of Glasgow north of the Clyde, and—south of the river—the ground between Renfrew and Barrhead, together with a small area of Coal Measures round Rutherglen.

The City of Glasgow north of the Clyde, and northern suburbs—with the exception of a small area around Springburn examined by Dr. Peach—were revised by Mr. Hinxman, who was also responsible for the central portion of the map between Maryhill and Chryston.

The area of Coal Measures immediately west of Coatbridge, between Gartcosh and Newlands, was revised by Mr. Clough ; the adjoining area between Shettleston and Baillieston, by Mr. Wright ; and the ground on either side of the Clyde, from Cambuslang to Bothwell, by the late Mr. Grant Wilson.

To Mr. Anderson were allotted the City and suburban areas south of the Clyde between Govan and Thornliebank, the northern slopes of the Cathkin Hills, and a small area of volcanic rocks around Cort-ma-law, on the Campsie Fells.

Dr. Lee has contributed a chapter on the Palæontology of the district. Analyses of limestones and cements are supplied by the late Mr. Grant Wilson, and of fireclays by Mr. E. G. Radley. We are indebted to Mr. Walter C. Hancock for "rational" analyses and results of physical tests of the same fireclays, and further notes on this subject have been contributed by Dr. Flett and Mr. J. A. Howe.

The bibliographical appendix has been compiled by Mr. D. Tait.

Acknowledgment should here be made of the valuable assistance afforded to the officers of the Survey during the progress of the revision by proprietors and managers of collieries, ironstone and fireclay workings, quarries and brickworks; mining and civil engineers; city officials; and many others too numerous to refer to by name. Full advantage has been taken of the observations made by local geologists in the west of Scotland and published in the *Transactions of the Geological Society of Glasgow.* No special account of the history of geological research in the Glasgow district is given in this memoir, but references are made in the different sections to their work.

Special thanks are due to Dr. Henry Woodward, F.R.S., for granting permission to use the block of the text figure 25 [now Fig. 23] which has already appeared in the *Geological Magazine.*

The general editing of the memoir has been in the hands of Mr. Hinxman, Mr. Clough being responsible for those portions dealing with the Coal Measures.

J. J. H. TEALL,
Director.

GEOLOGICAL SURVEY OFFICES,
28 JERMYN STREET,
LONDON, 13*th March* 1911.

PREFACE TO SECOND EDITION.

SINCE the publication of the first edition of this memoir in 1911, our knowledge of the Carboniferous rocks of the Glasgow district has been enlarged by the work of local geologists and of the officers of the Geological Survey. Consequently it has been necessary to recast the sections dealing with the divisions of the Carboniferous. Mr. C. H. Dinham is responsible for the revision of the Calciferous Sandstone sediments and Lower Limestone Group, and Mr. M. Macgregor for that of the Limestone Coal Group, Upper Limestone Group, Millstone Grit, and Coal Measures. In the previous edition a special chapter was devoted to the economic geology of the Glasgow district. Those portions of it dealing with the coals, ironstones and fireclays have been embodied in the stratigraphical account given in Chapters III. to VI. ; while for further information the reader is referred to three parts of "Economic Geology of the Central Coalfield of Scotland" (Area V., 1916 ; Area IV., 1920, and Area VII., 1920), which give a detailed account of most of the area included within the Glasgow Sheet. The rest of the Memoir, apart from minor corrections and additions, remains as in the first edition. Mr. E. B. Bailey has revised the chapter dealing with the igneous geology, and Mr. E. M. Anderson, in addition to rendering assistance with the stratigraphical portions, has revised his account of the faults and his description of the building-stones. One or two text figures have been omitted and several new ones added. The present edition has been edited by Mr. M. Macgregor.

J. S. FLETT,
Director.

GEOLOGICAL SURVEY OFFICES,
28 JERMYN STREET,
LONDON, 28*th November* 1924.

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CONTENTS.

CHAPTER I.

PAGE
INTRODUCTION 1
  i. Area and Physical Features 1
  ii. Distribution and Table of Formations and Rock Groups . . 2

CHAPTER II.

THE OLD RED SANDSTONE 5
  General Remarks 5
  i. Lower Old Red Sandstone 6
  ii. Upper Old Red Sandstone 6

CHAPTER III.

CARBONIFEROUS 10
  General Remarks 10
  Calciferous Sandstone Series 10
    1. Cementstone or Ballagan Group 11
    2. The Volcanic Rocks of the Clyde Plateau 13
    3. Upper Sedimentary Group 14
      General Description 14
      Detailed Description 18
        (a) Hurlet and East Paisley 18
        (b) Campsie and Kilpatrick 22
        (c) Corrie 28

CHAPTER IV.

CARBONIFEROUS (*continued*): Carboniferous Limestone Series . . 32
  Introductory Remarks 32
    1. Lower Limestone Group 34
      General Description 34
      Detailed Description 35
        (a) Hurlet and East Paisley 35
        (b) Kilpatrick 39
        (c) Braes of Campsie 40
        (d) Corrie 44
        (e) Glasgow and Country to East 46
    2. Limestone Coal Group 46
      General Description 46
      Detailed Description 48
        (a) Glasgow District: south of the Clyde 48
        (b) Glasgow District: north of the Clyde 53
        (c) Chryston 61
        (d) Kirkintilloch to Kilsyth 62
    3. Upper Limestone Group 67
      General Description 67
      Detailed Description 67
        (a) Glasgow District: south of the Clyde 67
        (b) Glasgow District: north of the Clyde 72
        (c) Kirkintilloch to Kilsyth 77

CHAPTER V.

PAGE
CARBONIFEROUS (*continued*) : Millstone Grit Series 80
General Description 80
Detailed Description 83
(a) Glasgow City and Suburbs 83
(b) Garnkirk and Glenboig 86
(c) Bishop and Woodend Lochs 91
(d) Outliers of the Kelvin Valley 92

CHAPTER VI.

CARBONIFEROUS (*continued*): Productive Coal Measures and Barren Red Measures 93
General Description 93
Detailed Description 95
(a) Glasgow City 95
(b) Rutherglen 96
(c) Cambuslang, Uddingston and Bothwell . . 99
(d) Shettleston and Baillieston 108

CHAPTER VII.

PALÆONTOLOGY OF THE CARBONIFEROUS ROCKS OF THE GLASGOW DISTRICT 119

CHAPTER VIII.

IGNEOUS ROCKS 135
Introductory Remarks 135
I. Superficial and Intrusive Igneous Rocks of the Volcanic Episode 135
Lavas and Tuffs of the Campsie Fells 137
Lavas and Tuffs of the Kilpatrick Hills 139
Lavas and Tuffs of the Cathkin Hills 140
Volcanic Vents 142
Dykes of the Volcanic Episode 147
Ungrouped Intrusions 148
II. Intrusions not definitely correlated with the Volcanic Episode 149
General Remarks 149
The Lennoxtown Essexite 152
The Kilsyth Quartz-Dolerite Sills 153
The East-and-West Quartz-Dolerite Dykes . . . 156
The Milngavie Dolerite Sills 159
The Teschenitic Sills (including the Barshaw Theralite or Bekinkinite) 160
The West-North-West Dolerite Dykes 163
III. The Petrology of the Igneous Rocks 164
Introduction 164
The Lennoxtown Essexite 169
The Cathcart Nepheline-Teschenites 171
The Glasgow Teschenites 172
The Paisley Sills with the Barshaw Theralite or Bekinkinite 173
The Milngavie Sills 175
Lavas and Associated Intrusions of Calciferous Sandstone Age, including :—
Macroporphyritic Basalts ; Microporphyritic Basalts ; Mugearites ; non-mugearitic Trachybasalt ; Trachyandesite ; Phonolite ; Trachytes ; Felsites . . . 175
Quartz-Dolerite Sills of Kilsyth and East-and-West Dykes 186
IV. Zeolites of the Kilpatrick Hills 188

CHAPTER IX.

PAGE
GEOLOGICAL STRUCTURE 191
Description of General Section across the Ground 191
Description of Local Horizontal Sections 192
Campsie and Kilpatrick Hills 192
Campsie and Milngavie Area 192
Kirkintilloch and Kilsyth 192
Glasgow and Chryston 198
Western Area 198
Southern Area—Pollokshaws and the Cathkin Hills . . 202
Shettleston and Uddingston District 206

CHAPTER X.

FAULTS 207

CHAPTER XI.

PLEISTOCENE AND RECENT 214
Glacial 214
Introductory Remarks—Sequence of Events 214
(1) Pre-glacial Topography 215
(2) Submergence of the Ancient Land Surface. . . . 218
(3) Direction of Ice-Movements as indicated by striæ, carried boulders and drumlins 220
Boulder-Clay 223
Campsie and Kilpatrick Hills 223
Glasgow and the Central Plain 223
Coatbridge District 226
Sands, Gravels and Brick-Clays of the Central Plain . 227
(4) Retreat Phenomena of the Campsie Fells 228
(5) Deposits of the Post-Glacial Terraces 230
The 100-foot Terrace—Brick-Clays—Lower Terraces . . 230
Freshwater Alluvium 233
River and Lake Terraces 233
Peat 234

CHAPTER XII.

PHYSICAL FEATURES 235
General Remarks—River Systems—The Clyde—The Endrick . . 235
Topography of Glasgow and the Central Plain. . . . 236
Area South of the Clyde 237
Area North of the Clyde and West of Glasgow . . . 237
The Campsie and Kilpatrick Hills 238
Influences of geographical and geological conditions on the history of Glasgow 241

CHAPTER XIII.

LIMESTONES, ROAD METAL, BUILDING STONES, WATER SUPPLY . . 243
1. Limestones and Cements 243
General Remarks 243
Analyses 243
2. Setts and Road Metal 250
3. Building Stones, Moulding and Building Sand and Refractory Sandstones 252
(i) Stratigraphical Position of the Sandstones of Economic Value within the Glasgow District 252
(ii) Building Stones from External Sources chiefly employed in Glasgow 257
(iii) Physical and Microscopical Characters and Weathering Qualities of the Sandstones 258
Analyses of Four Building Stones from the Glasgow District 264
List of Stones used in Buildings in Glasgow City . . 265
4. Water Supply 266
The Loch Katrine Water Supply—The Gorbals Reservoirs—The Westhorn River Supply Works—Wells—Old Coal Wastes—Reservoirs on the Campsie Fells and Cathkin Hills . . 266

APPENDIX I.

PAGE
List of Works relating to the Geology of the Glasgow District . . 269

APPENDIX II.

Glossary of Mining Terms, etc., used 283

LIST OF ILLUSTRATIONS.

LIST OF FIGURES IN TEXT.

PAGE
FIG. 1. Sketch Map of Killearn District 5
„ 2. Comparative Vertical Sections, Lower Limestone Group, with upper portion of the Calciferous Sandstone Series . 33
„ 3. Comparative Vertical Sections, Limestone Coal Group . . 47
„ 4. Comparative Vertical Sections, Upper Limestone Group . 68
„ 5. Vertical Section of strata at Bishopbriggs 77
„ 6. Sketch Map showing vents and intrusions in the Campsie Fells. 143
„ 7. Section across the Dumgoyn and Dumfoyn vents, and the bedded lavas of the Campsie Fells 144
„ 8. The Meikle Bin and Little Bin 147
„ 9. Composition Diagram of Quartz-Dolerites 187
„ 10. Section from Balmore across the South Hill of Campsie . . 193
„ 11. Section from East to West across the South Hill of Campsie . 193
„ 12. Section across the "Riggin" from Twechar to Auchinbee . 195
„ 13. Section across the "Riggin" from Croy Hill to Kilsyth and thence north-west across the Braehouse anticline . . 195
„ 14. Section across the "Riggin" from Auchinbee to the Queenzieburn Fault 197
„ 15. Section from Woodilee across the St. Flanan basin to the Queenzie Pit 197
„ 16. Section from the Clyde across the east end of Glasgow to Lenzie 199
„ 17. Section across the Garnkirk basin to the Luggie Water . . 199
„ 18. Section across the Western District 200
„ 19. Mine Section in Blairdardie Pit 201
„ 20. Section across the Arden basin from near Holm to Pollokshields 204
„ 21. Section from near Gartloch to near High Blantyre . . . 205
„ 22. Section showing the relation of the Westerhouse Teschenite Sill to an east-and-west fault 210
„ 23. Sketch Map showing distribution of essexite boulders through the Central Valley 221
„ 24. Sketch Map illustrating Phenomena of Local Glaciation in the Campsie Fells 229
„ 25. Drainage System of the Campsie Fells 239
„ 26. Microslide of Blochairn Refractory Sandstone . . . 263
„ 27. „ „ Blochairn Moulding Sandstone 263
„ 28. „ „ Kirkburn Sandstone 263
„ 29. „ „ Giffnock Sandstone 263
„ 30. „ „ Kaolin from Germiston Sandstone . . . 263

FOLDING PLATE—
Contour Map of the Rock Surface round Glasgow after removal of the superficial deposits . . . . *At the end of volume.*

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THE GEOLOGY OF THE GLASGOW DISTRICT

CHAPTER I.

INTRODUCTION.

i. Area and Physical Features.

The country shown upon the Glasgow District Map, and described in this memoir, represents an area of 229½ square miles situated chiefly within the counties of Lanark and Stirling, but containing also portions of Dumbarton and Renfrew. This area is divided almost equally between Sheets 30 and 31 of the Ordnance Survey, and also includes a narrow strip along the northern margin of Sheets 22 and 23, added to the map in order to show the southern extremity of the Arden basin.

The limits of the map extend southward from Killearn and Fintry on the north side of the Campsie Fells to Barrhead and High Blantyre south of the Clyde; the towns of Kilsyth, Coatbridge and Hamilton lying just beyond its eastern margin. The City of Glasgow and its suburbs occupy almost the whole of the south-western quarter of the area.

The principal physical features of the district may be described in a few words as a gently undulating central plain of drift-covered Carboniferous rocks, flanked to the north by the steep-fronted volcanic plateau of the Kilpatrick Hills and Campsie Fells, the latter reaching a height of 1894 feet at Earl's Seat, and bounded on the south by the lower escarpments of the Cathkin and Renfrewshire volcanic ranges.

The valley of the Clyde crosses the southern part of the area in an oblique direction. Below Carmyle the river flows through a flat belt, widening to the west, of recent and late glacial superficial deposits; between Bothwell and Uddingston its course, like that of its tributary the Rotten Calder, is largely through rock-gorges.

The Kelvin runs parallel to the escarpment of the Campsie Fells through a wide drift-filled valley which it leaves near Killermont, and, turning at right angles to its former course, flows in a deep post-glacial gorge through Glasgow to the Clyde.

A more detailed account of the surface features of the different areas will be found in Chapter XII.

ii. GENERAL DISTRIBUTION OF FORMATIONS AND ROCK GROUPS IN THE AREA.

The geological formations represented within the area of the Glasgow District Map are given in stratigraphical order in the following table.

SEDIMENTARY ROCKS.

Pleistocene and Recent		Peat.
		River Terraces and freshwater alluvia.
		Raised Beach deposits.
		Glacial sands, gravels and brick-clays.
		Moraines.
		Boulder Clay.
Carboniferous	Upper	Barren Red Measures.
		Productive Coal Measures.
		Millstone Grit.
	Lower	Carboniferous Limestone Series.
		Calciferous Sandstone Series
Old Red Sandstone	Upper.	
	Lower.	

IGNEOUS ROCKS.

A. Contemporaneous.

In Calciferous Sandstone Series.	Lava flows of Basalt of Dalmeny type.
	,, ,, Jedburgh type.
	,, ,, Craiglockhart type.
	,, ,, Dunsapie type.
	,, ,, Markle type.
	,, Mugearite.
	Basaltic Tuff.
In Upper Old Red Sandstone.	Lava flows ? of Basalt of Jedburgh type.

B. Intrusive.

Tertiary ?—W.N.W. dykes of Olivine-Dolerite.
Permo-Carboniferous ?—Sills and East-and-West Dykes of Quartz-Dolerite.

Carboniferous ?	Sills of Teschenite, Theralite and Olivine-Dolerite.
	Plug of Essexite.
Definitely connected with volcanic episode of Calciferous Sandstone Times.	Basalt and Dolerite of Jedburgh type.
	,, ,, Dunsapie type.
	,, ,, Markle type.
	Trachyte, Felsite, Trachyandesite and Trachybasalt.
	Basaltic and Trachytic Tuff in Vents.

The oldest rocks included in the Glasgow District Map belong to the Old Red Sandstone, both the Upper and Lower Divisions of this formation being represented in the north-western corner of the Sheet. The lower group is restricted to a small outcrop around Killearn; the strata of the upper division flank the western and north-western slopes of the Campsie Fells, where they are well exposed in the deep channels cut by the hill burns, and reappear in a small outlier ten miles further to the east, on the southern border of the same range.

The rest of the ground—with the exception of a few igneous intrusions of uncertain age—is covered by the sediments and contemporaneous and intrusive igneous rocks of the Carboniferous Period.

The lower division, comprising the Cementstone or Ballagan Group, of the Calciferous Sandstone Series, forms a continuous outcrop round the northern and western faces of the Campsie Fells as far as the village of Strathblane, and is seen in occasional exposures in the hill streams as far east as the Campsie Glen.

The upper sedimentary group that overlies the volcanic rocks occupies two small isolated areas in the folded and faulted region south of the great Campsie fault—the one at Milton of Campsie, the other west of Corrie; good natural sections being exposed at both localities. These sediments further extend in an irregular belt from Lennoxtown to the margin of the map west of Milngavie, and reappear south of the Clyde around Hawkhead.

To the great volcanic outburst of Calciferous Sandstone times are due at once the greater part of the igneous rocks found within the Glasgow district and the most striking features in its surface relief. In the north lava-flows give rise to the terraced plateau of the Campsie Fells and successive escarpments of the Kilpatrick Hills; and in the south form such part of the Cathkin Hills as falls within the limits of the map. The neighbourhood of Fintry, in the northern district, also affords several fine exposures of the volcanic vents of the period, deeply dissected by erosion. Numerous minor intrusions in the same district are also referable to this volcanic episode.

The rocks of the Carboniferous Limestone Series occupy considerably the largest area of sedimentary strata included in the map. In the eastern half of the ground they extend from the foot of the Campsie Fells to the parallel east-and-west faults by which they are brought into contact with the Millstone Grit of the Garnkirk basin and the Coal Measures of the Shettleston district. In the west they stretch from the north side of the Kelvin valley—where they rest either conformably upon or in faulted conjunction with the Calciferous Sandstone—to the southern margin of the Sheet. Covered to a large extent by superficial deposits, Carboniferous Limestone strata also underlie a large part of the area upon which the City of Glasgow and its suburbs are built.

The Lower and Middle Group of this Series are most largely developed in the western and north-western parts of the area, the best natural sections of the lower limestones being obtained in the Campsie district. The Upper Limestone Group is chiefly confined to the central plain to the north-east of Glasgow; but also occupies the Arden basin between Barrhead and Cathcart, where excellent sections of these limestones are to be found.

The Millstone Grit covers but a small proportion of the surface under description, being practically confined to two narrow belts, one of which occupies the centre of the Garnkirk semi-basin; the other extends through the centre of the City between Germiston and Pollokshaws, and is truncated at either end by a powerful fault.

The south-eastern portion of the map is filled by the western extremity of the Lanarkshire coalfield. The Productive Coal Measures occupy the surface on the north side of the Clyde between Coatbridge and the centre of the City, and extend westward on the south side of the river from Cambuslang to Rutherglen and Pollokshields. On the south they are cut off by the Dechmont fault, by which they are brought into contact, first, with the volcanic rocks of the Cathkin Hills, and, further to the west, with the Carboniferous Limestone strata of the Arden basin.

The Barren Red Measures are chiefly developed in the neighbourhood of Uddingston, on either side of the Clyde. They also form a narrow, interrupted strip to the north of the Mount Vernon fault, between Coatbridge, Baillieston and Shettleston.

In the following pages, which are intended to serve primarily as an educational handbook to the geology of the Glasgow district, it would be out of place to attempt to give any historical account of the labours of former observers in the different fields of geological research.

References will be found in the body of the work to the individual papers bearing on particular points as they arise, and for fuller information as to the contents of the numerous papers on the Geology of Glasgow and its neighbourhood that have appeared during the last fifty years, the reader is referred to the excellent volume on the History of the Glasgow Geological Society published in 1908 in commemoration of the Jubilee of that Society, in which will be found a *résumé* of the principal papers on local geology published in the Society's Transactions. A further list of the principal works on the geology of the district is given in Appendix I. L. W. H.

CHAPTER II.

THE OLD RED SANDSTONE.

The Old Red Sandstone of the Central Valley of Scotland has been divided into an upper and a lower division, which are palæontologically distinct, and are, moreover, separated by an important unconformity.

Both divisions, as already stated, are represented in the Glasgow District. They were identified by Dr. Jack on lithological grounds alone, since fossils have never been found in this locality; while, to add to the difficulties, there is no direct evidence of the unconformity elsewhere so strikingly developed.

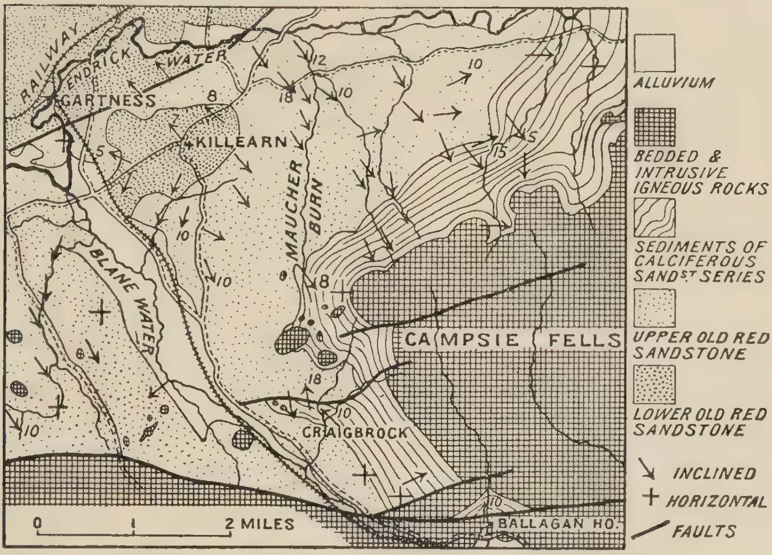

FIG. 1.—Sketch Map of the Killearn District.

The lower group consists of purplish and red-brown ashy-looking sandstones which outcrop in the neighbourhood of Killearn (Fig. 1). These sandstones carry numerous pebbles of Old Red Sandstone lavas and closely resemble the undoubted Lower Old Red Sandstones which occur further to the north, associated with fossiliferous bands.[1]

The upper group is for the most part composed of brick-red sandstones, which are distinguished from those of Killearn alike by their colour and by the presence of quartz instead of andesite pebbles; to the south this upper group passes conformably beneath the basement beds of the Carboniferous System.

---

[1] R. L. Jack, and R. Etheridge, Jun., 'On the Discovery of Plants in the Lower Old Red Sandstone of the Neighbourhood of Callander,' *Quart. Journ. Geol. Soc.*, vol. xxxiii., 1877, p. 213.

i. LOWER OLD RED SANDSTONE.

To illustrate the mode of occurrence of the Lower Old Red Sandstone outcrop of the Glasgow District Map, it is necessary to include in the consideration a small portion of the adjoining district (*see* Fig. 1). The best exposures of the group are afforded by the picturesque linn through which the Endrick flows at Gartness. The sandstones here dip gently up-stream, and one of their members, more resistant than the others, crosses the bed of the river, giving rise to a small waterfall. The cliffs on either side show alternations of hard and soft beds, which stand out as crags or serve as sheltering hollows for the pendent vegetation. The hard beds are fairly coarse purple-brown or finer red-brown ashy-looking sandstones. The more purple beds frequently contain well rounded pebbles of andesite, with a few of the Highland schists. The pebbly beds are best seen on the north-eastern bank, few pebbles occurring on the other side further down-stream than the waterfall. The softer beds are generally somewhat clayey; they are, however, of much the same general nature and colour as the sandstones, although occasional thin bands of red and green shales also occur.

The outcrop of these purplish-brown beds is suddenly cut off to the south by an east-and-west fault, presumably the continuation of the fault which further to the north-east forms the southern boundary of the Ochil Hills. The hade of the fault is normal, being steep to the south, as may be clearly seen in the good exposure afforded by the cliff on the western bank. The dislocation introduces a different set of brick-red sandstones which can easily be distinguished in colour from those to the north. These are the Upper Old Red Sandstones. At first they dip gently from the fault and then flatten out. At the fault itself one of the beds contains subangular pebbles of quartz, but no andesite, thus agreeing with other pebbly beds of the Upper Old Red Sandstone elsewhere in this district.

The Killearn outcrop appears to mark the central portion of a gentle dome which brings the Lower Old Red Sandstone to the surface south of the Ochil fault. The rocks included in this outcrop show no signs of greater folding than the surrounding strata of the upper division. Lithologically they are identical with those of the Gartness exposures, and their widely distributed and well rounded pebbles, occurring in nests and layers and not forming persistent bands of conglomerate, consist for the most part of lava-form rocks, and but rarely of schists. The igneous pebbles noted are all of rock-types characteristic of the volcanic activity of the period—augite- and hornblende-andesites and occasionally rhyolite. They represent the waste of the great volcanic group so typically developed in the Ochils.

Exposures in streams and small quarries are everywhere abundant and are sufficiently indicated in the accompanying sketch map.

ii. UPPER OLD RED SANDSTONE.

Three sub-divisions can be recognized in the Upper Old Red Sandstone of the Glasgow Map—these are in descending order :—

3. White siliceous sandstones, conglomeratic towards the base and with bands containing cornstone concretions—50 to 100 feet.

2. Red, purple, and white sandstones, with bands containing cornstone concretions—about 500 feet.

1. Red sandstones with very subordinate red marls—about 2000 feet seen.

1. *Red sandstones with very subordinate red marls.*—This lower sub-division is exposed to advantage in the glens to the north of the Campsie Fells, and best of all in the striking gorge of the Maucher Burn. The rocks mostly consist of soft brick-red sandstones, as a rule finely laminated and not often current-bedded. They weather in a massive fashion, and the lamination frequently shows merely as a colour banding. Pebbles are not abundant, but occur at various levels, either scattered through the sandstone or crowded into definite layers. They consist for the most part of vein quartz, together with quartzite and other schists. The andesite pebbles, so abundant in the Lower Old Red Sandstones, are here absent.

The prevalence of quartz in the conglomerate bands is an example of the survival of the fittest. Probably the winnowing of the hard from the soft, in this instance, was brought about by atmospheric weathering, since the pebbles are subangular and have evidently not been greatly water-worn.

It must not be supposed, however, that absence of igneous pebbles is a constant feature of the Upper Old Red Sandstone of Scotland. In the immediate neighbourhood of large uncovered masses of Lower Old Red Volcanic rocks the reverse is true, and the Upper Old Red Sandstone of Edinburgh, for instance, has received abundant tribute from the wasting volcanic chain of the Pentlands.

In such cases it is fairly certain that the pebbles were detached and deposited by floods originating in the hills, and thus escaped the full ordeal of weathering which determined the constitution of the deposits forming at greater distances from the upland tracts.

2. *Red, purple and white sandstones, with bands containing cornstone concretions.*—No definite boundary can be traced on the map between the monotonous red sandstones just described and the more variegated assemblage which overlies them in the Campsie district. The Maucher Glen already mentioned affords a fair section of the group under consideration, but better exposures are met with in the glen draining into Strathblane east of Craigbock. The prevalent rock type is a soft sandstone, sometimes of the red colour characteristic of the lower divisions, but very often purple or white and sometimes yellow. The soft purple sandstones, which can readily be dug into with a hammer, not infrequently carry concretions of very impure calcareous material known as cornstone. There are several beds too, which have a calcareous matrix, and are hard enough to form ribs crossing the bed of the burn. They weather pale yellow but on a fresh fracture sometimes show blue. Cornstone concretions are also found in seams of purplish clay. They often present a very curious appearance, with their longer axes arranged at right angles to the bedding planes of the containing rock.

The section just described is repeated by a fault in the western branch of the glen, and in this second exposure a ten-foot band of coarsely crystalline cornstone gives rise to a waterfall in the course of the stream, but its occurrence must be extremely local since no such bed has been met with elsewhere in the Campsie district.

3. *White siliceous sandstones, conglomeratic towards the base and with bands containing cornstone concretions.*—The thickness of the top sub-division of the Upper Old Red Sandstone in the Campsie district is much less than that of either of its fellows. At the same time it constitutes a readily recognized and constant horizon, and its base line is accordingly indicated on the map.

The conglomeratic nature of the bottom beds is due to the presence of large pebbles of quartz more or less irregularly distributed. The group seems to correspond to the Whitta Sandstones of the North of England, and is especially interesting in that it apparently represents a true passage zone into the Carboniferous system. The lower and major portion of the group is linked with the Old Red Sandstone through intercalation with cornstone bearing beds, while the upper part is interleaved with green shale and cementstone of the type occurring in the basement Carboniferous in what is known as the Ballagan Series. The sandstones and quartz-conglomerates themselves are throughout of typical Carboniferous character. They resemble exactly, as was recognised by Dr. Young,[1] the beds occurring above the main mass of the Ballagan shales and cements. They are also precisely similar to the Craigmaddie Muir Sandstones above the volcanic group.

An inlier of the Upper Old Red Sandstone is exposed on the eastern margin of the map, underlying the lavas of the Kilsyth Hills and bounded to the south by the fault which forms the southern limit of the Campsie Fells. In accordance with the custom of the time, Dr. Peach placed these rocks in the basement group of the Carboniferous System ; their allocation to the Upper Old Red Sandstone involves a change of nomenclature, not of interpretation.

The sandstones themselves differ markedly from those exposed to the north-west of the Campsie Fells in their prevalent yellow colour. They are generally gritty in texture and sometimes carry scattered pebbles of quartz. Their matrix has apparently been calcareous, and they weather readily, becoming very friable. They not infrequently contain cornstone concretions in beds with green and purple marly matrix. At one point in the Garrel Burn several superposed concretionary layers of cornstone have an aggregate thickness of eight feet.

The presence of cornstones is a very useful link in uniting these Garrel beds with the upper portion of the Upper Old Red Sandstone not only in the district previously described but everywhere else in Scotland. J. G. Goodchild[2] has interpreted this general appearance of cornstones as denoting a climatic change in anticipation of the incoming of Carboniferous conditions.

The interesting and difficult question as to the physical conditions under which the Old Red Sandstone deposits accumulated, has ever been a fertile source of differences of opinion. Fleming, Godwin-Austen and Ramsay held that the Old Red Sandstones were formed in inland lakes, a view elaborated by Sir Archibald Geikie. Goodchild believed them to be the product of desert conditions. These two conceptions may be grouped together as the *continental*, in contrast to the *marine* interpretation, still advocated by Prof. Peter Macnair[3] and other authors. It seems to the present writer that the continental interpretation is in best accord with the lithological and palæontological features which distinguish the Old Red Sandstone from the undoubted marine accumulations represented in the geological record. It is thought, too, that the more general conception of the formation as a continental deposit is likely to be of greater value than the more limited lake hypothesis. In especial it seems probable that contemporary river-action has received too little attention, particularly in connection with the formation of great masses of conglomerate and the dispersal of fish remains.

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[1] J. Young, 'On the Geology of the Campsie District,' *Trans. Geol. Soc. Glasg.*, vol. i., part i., 1860, p. 14 ; revised and reprinted 1868, p. 22, and 1893, p. 27.

[2] 'Geological History of Lower Tweedside,' *Proc. Geol. Assoc.*, 1903, pp. 118-120.

[3] The reader will be well repaid on turning to Prof. M'Nair's Presidential Address, 'The Physical Conditions under which the Deutozoic Rocks of Scotland were Deposited. Part i, the Old Red Sandstone,' *Trans. Geol. Soc. Glasg.*, vol. xvii., part i, 1922, pp. 105-145.

Recently Mr. Maufe[1] has found that cornstones, similar to those which are so characteristic of the upper part of the Upper Old Red Sandstone in the Glasgow district and elsewhere throughout Scotland, are forming to-day under continental conditions in tropical Africa. The kankar, as the modern cornstone is called, is a terrestrial subsoil formation, and it is extremely probable that the Old Red Sandstone cornstones had a similar origin. E. B. B.

[1] ' Summary of Progress for 1909,' *Mem. Geol. Surv.*, 1910, p. 35.

CHAPTER III.

CARBONIFEROUS.

THE rocks of the Carboniferous System, as already stated, occupy by far the largest portion of the area, and are also of the highest importance as the source of the mineral wealth which has made Glasgow and the surrounding country the most populous centre of industry in Scotland.

In the variety of its sedimentary and igneous accumulations the Scottish development of the Carboniferous is unsurpassed. The Glasgow district is thoroughly representative in this respect, and Glasgow geologists have taken full advantage of the opportunities thus provided.

The boundary-line between the Upper and Lower Carboniferous strata of Scotland, based upon the work of the late Dr. Kidston [1] on the fossil plants, and of the late Dr. Traquair [2] on the fossil fishes, has been drawn at a position approximately 50 to 100 feet above the base of the Millstone Grit. The Lower Division thus includes the Calciferous Sandstone and Carboniferous Limestone Series with the addition of a small portion of the Millstone Grit; the remainder of that group, together with the Productive Coal Measures and Barren Red Measures, forms the Upper Division. A list of the Carboniferous plants of the West of Scotland, by Dr. Kidston, and of the fishes, by Dr. Traquair, will be found in the Handbook prepared for the British Association meeting in Glasgow in 1901.[3] L. W. H.

CALCIFEROUS SANDSTONE SERIES.

A rough three-fold division of the Calciferous Sandstone Series of the Glasgow district is rendered possible by taking advantage of the great volcanic group of the Clyde Plateau, which, over wide areas, occupies a position somewhere about the middle of the Series. Beneath the volcanic rocks occurs the Cementstone Group of Ballagan, while above them a considerable thickness of sediment, often in part conglomeratic or otherwise abnormal in character, is usually encountered before reaching the base of the Carboniferous Limestone Series. The grouping here indicated is complicated by the fact that at some points the volcanic episode originated much earlier than at others.

[1] 'On the Various Divisions of British Carboniferous Rocks as determined by their Fossil Flora,' *Proc. Roy. Phys. Soc. Edin.*, vol. xii., 1894, pp. 183-258. 'Divisions and Correlation of the Upper Portion of the Coal Measures,' *Quart. Journ. Geol. Soc.*, vol. lxi., 1905, pp. 308-321. 'Fossil Plants of the Carboniferous Rocks of Great Britain,' Part 1, *Mem. Geol. Surv.*, 1923, pp. 8, 9, 13.

[2] 'Fossil Dipnoi and Ganoidei of Fife and the Lothians,' *Proc. Roy. Soc. Edin.*, vol. xvii., 1891, pp. 385-400. 'On the Distribution of Fossil Fish-remains in the Carboniferous Rocks of the Edinburgh District,' *Trans. Roy. Soc. Edin.*, vol. xl., 1905, pp. 687-707 (issued separately 1903).

[3] Geological portion, with corrections and additions, reprinted by the Glasgow Geological Society in 1904 under the title, 'Geology and Palæontology of the Clyde Drainage Area.'

1. The Cementstone or Ballagan Group.

The basement group of the Carboniferous System is so finely developed in the Campsie district that Ballagan of Strathblane has always been regarded as the type locality of the group in Scotland, just as is Tweedside in the North of England. The great bulk of the Ballagan Beds consists of about 600 feet of alternating green clay-shales and cementstones, with subordinate micaceous sandstone bands. Towards the base of the group the shales and cementstones interleave with the upper twenty or thirty feet of the white sandstone, which, as already described, furnishes a passage zone linking the Upper Old Red Sandstone to the Carboniferous System. This sandstone is unfortunately cut out by the Campsie fault in Ballagan Burn, but is well exposed in numerous sections to the north. At their summit the shales and cementstones pass, also with intercalation, under another sandstone of exactly the same type and ranging up to about 100 feet in thickness. This may be called for convenience the Spout of Ballagan Sandstone, since over it the well-known spout or waterfall leaps into the hollow excavated in softer beds below.

The outcrop of the Ballagan Beds is continuous along the north and west face of the Campsie Fells as far as Strathblane, where it is interrupted by a branch of the Campsie fault. To the east the group is again exposed in the Ballagan Burn, and also in the Fin and Campsie Glens, while there is another small outcrop two and a half miles still further to the east, bounded apparently by a fault to the north as well as to the south. In the Garrel Burn district the position of the group is mainly taken by lavas and tuffs, but here and there intercalations of shales and cementstones may be detected among these volcanic rocks.

The interesting inlier of sediments, surrounded on all sides by volcanic rocks, which was discovered by Dr. Jack in the valley bottom north-east of the Meikle Bin, is very poorly exposed. The rocks seen are sandstone, shale and cementstone. In part at least they owe their exposure at the surface to doming, which is apparently connected with the intrusion of a felsitic laccolith.

The type section of the Ballagan Beds, afforded by the Spout of Ballagan, is situated in private grounds about half a mile from Strathblane station. Following up the burn from the road, one readily locates the Campsie fault, which at this point brings the porphyritic lavas of the upper part of the Campsie-Kilpatrick succession to the south into juxtaposition with the underlying shales and cementstones to the north. The exposures in the lower portion of the burn are good, but need not detain the visitor, who should proceed at once to the magnificent cliffs trenched by the stream for fully a hundred yards below the present position of the waterfall.

The alternating character of the main portion of the deposit is shown here to great advantage : in 130 feet at least 100 distinct bands of cementstone can be counted ; these range from a few inches up to a foot or so in thickness, and the intervening shales vary in like manner.

Several observers have recognized the rhythm of the ancient formative processes which finds expression to-day in the striped and banded cliffs of Ballagan. What were the conditions which regulated this constantly repeated cycle of deposit ? It does not seem altogether impossible that the rhythm may have been one of seasonal change ; that the shales are the muds of successive rainy seasons washed down into more or less land-locked lagoons, and that the cementstones are the chemical precipitates[1] deposited from the concentrated waters of the latter during intervening periods of drought. On the whole, however, this hypothesis seems to involve too rapid an accumulation, unless, indeed, very liberal allowance is made for seasons which may have run their course without leaving any deposit behind. Analogy too, with certain other cases of recurrent changes of sedimentation in the Scottish Carboniferous suggests a geographical rather than a climatic oscillation as the underlying cause.

At intervals in the deposit exposed in the Ballagan section, and without any recognisable relation to the rhythm of its accumulation, bands of sandstone run evenly across the cliff face, forming projecting ribs two or three feet thick. They are regularly bedded, although sometimes ripple-marked, white or red in colour and very micaceous, their surfaces gleaming with flakes of biotite and muscovite. They resemble the micaceous sandstones which are so much more strongly developed in the same group in East Lothian, but differ markedly from the overlying Spout of Ballagan Sandstone, great blocks of which litter the bottom of the gorge beneath the waterfall.

Before noticing the variations of the group in other localities, a slightly more detailed description should be given of the two main rock types.

The cementstones of Ballagan are argillaceous dolomites, as shown by J. Wallace Young in his valuable paper on the subject.

ANALYSIS OF 8 CEMENTSTONES FROM BALLAGAN, BY J. W. YOUNG.[2]

	Dried at 100° C.							
	1	2	3	4	5	6	7	8
Insoluble .	18·12	22·40	18·40	21·60	13·59	20·50	20·55	23·25
Lime . .	24·16	23·35	23·80	23·50	26·99	24·25	24·10	23·00
Magnesia .	16·35	14·15	17·20	14·25	17·21	15·00	15·15	15·10

They are grey in colour, with a somewhat flinty fracture, weather cream-white and are practically unfossiliferous. They are nodular to a slight extent, so that exposed bedding planes have a lumpy uneven appearance. Bare surfaces, especially bedding planes, are apt to develop a reticulate set of close joints, and weather exactly like the fine-grained margins of basic igneous intrusions.

The shales show their bedding clearly, but are not fissile and always break up into very small pieces in natural exposures. Their colour varies from a pale grey-green to a deep blue-green, while in a few cases they are red. These red shales occur interbedded with the normal green shales from which apparently they differ only in colour. Possibly the redness is a secondary character, as at Dunbar, where it affects large masses of the deposit.

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[1] Dr. Young was always of opinion that the cementstones should be regarded as chemical precipitates. He also records the occurrence of gypsum at one point in the Ballagan cliff.—" Two varieties of gypsum occur at Ballagan; one of a red colour in veins intersecting the strata nearly at right angles; the other of a yellowish colour, and fibrous structure, appearing in laminæ between the beds." J. Young, *op. cit.*, 1860, pp. 17, 18; 1868, p. 27; 1893, p. 31. Even the latter are veins and not beds, but their presence here and in other sections of the group probably indicates that gypsum was originally deposited along with the shales and cementstones.

[2] 'On the Ballagan Series of Rocks,' *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, p. 211.

The micaceous sandstones intercalated among the shales have already been described. The massive Spout of Ballagan Sandstone is a hard white siliceous sandstone, showing little tendency towards the pebbly character which often becomes strongly marked further north. In the type section it is about forty feet thick, and is overlain by six feet of fireclay with numerous coal streaks, above which is a thin bed of sandstone followed by the lavas. A small intrusion may be seen cutting the beds immediately underlying the lavas at the side of the stream.

In following the group northwards around the base of the lava escarpment an important deterioration takes place in the character of the cementstone bands, which are frequently represented by grey marls or become altogether indistinguishable from the associated shales. The cementstone bands in the upper part of the section still remain fairly well represented. The best section in this northern district is that of the Little Corrie west of the Corrie of Balglass. Here too the Spout of Ballagan Sandstone is developed in its northern facies —thick and pebbly, the pebbles mostly consisting of quartz. It is interesting to find at the north-east angle of this corrie a bed of fireclay with coaly layers overlying the sandstone and underlying the volcanic rocks just as at Ballagan—so constant is the horizon of the base of the volcanic group in this district.

In Fin Glen, the Spout of Ballagan Sandstone can scarcely be said to be represented at all, and the same is true in the Campsie Glen. Perhaps the volcanic rocks reached this portion of the district somewhat earlier than Ballagan, but it is equally probable that the sandstone naturally thinned away in this direction for it is not half so thick at Ballagan as it is to the north. As observed by Dr. Young, Campsie Glen is situated in the region of maximum development of the cementstones.

In the Garrel Burn the position of the Ballagan Beds is taken by volcanic rocks. Vulcanicity appears to have made an intermittent start here in Upper Old Red Sandstone times, and continued right through the interval occupied by the deposition of the Ballagan Beds and the Spout of Ballagan Sandstone to the west. A few intercalations of cementstone and shale occur interleaved among these early lavas and tuffs, and the cementstone bands are sometimes sandy. There is a fine exposure of one of these intercalations in the stream east of the angle of the Campsie fault north-east of Corrie.

2. The Volcanic Rocks of the Clyde Plateau.

When the igneous rocks of the Central Valley of Scotland came to be classified, great uncertainty existed as to the age of the volcanic rocks so typically developed in the Campsie Fells. Dr. John Young showed[1] that they clearly overlie the Cementstone Group at Ballagan, but, misled by the Campsie fault, thought that they passed transgressively on to the Carboniferous Limestone Series near Lennoxtown. Sir Archibald Geikie, on the other hand,[2] first grouped them tentatively with the Old Red Sandstone. Further research, especially Dr. Jack's survey of the district, has since unravelled the complicated faulted structure of the region, and shown conclusively that the Campsie Fell lavas belong to the Calciferous Sandstone like the Arthur Seat lavas of the Edinburgh district. The detailed consideration of the volcanic rocks is reserved for Chapter VIII. E. B. B.

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[1] *Op. cit.*, 1860, p. 8 and plates.

[2] *Trans. Roy. Soc. Edin.*, vol. xxii., 1861, p. 633.

3. THE UPPER SEDIMENTARY GROUP.[1]

This Group embraces all the strata between the Clyde Plateau lavas, and the Hurlet Seam (p. 32), which throughout this memoir and in recent Survey publications is taken as the base of the Carboniferous Limestone Series.

The Hurlet datum-line.—Geologists in the west of Scotland have long been accustomed to include this group in their Lower Limestone Series of the Carboniferous Limestone—a practice followed in the earlier Survey publications ;[2] but the Hurlet Seam has been found to be so convenient a boundary for the purposes of mapping throughout Central Scotland, that it has been in general use by the Survey for a quarter of a century.[3] Objection has been taken to the Hurlet boundary because on both sides of it the marine invertebrate fauna is of Carboniferous Limestone type.[4] This has indeed been recognized from an early period, and, were it admissible to consider the Glasgow District without reference to other parts of Scotland, a return to the earlier usage might perhaps be justified. But when wider areas are taken into account this is seen to be impracticable, since the application of the same argument would abolish the use of the term Calciferous Sandstone for the Oil-Shale Group, and indeed even for its remaining and most typical member, the Cementstones. For the Cementstones of Liddisdale contain a thoroughly marine fauna, " characteristic of the Carboniferous Limestone Series " ;[5] nearer at hand the same description has been applied to the faunas found low down in the Oil-Shale Group or its equivalent in East Fife[6] and Midlothian ;[7] while still closer to Glasgow, in the Cobbinshaw district, encrinital limestones are known below the Burdiehouse seam,[8] and among the upper oil-shales in the same neighbourhood are found marine bands which can be followed with certainty into the " Lower Limestone Series " of Strathaven, and even to East Kilbride.[9] In fact it is scarcely possible to indicate a definite horizon below which marine faunas of Carboniferous Limestone type do not occur, so that the objection advanced against the Hurlet datum could be applied to any lower line that might be suggested, and cannot be maintained without making "Carboniferous Limestone of Scotland" almost synonymous with "Lower Carboniferous."

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[1] *See* Fig. 2.

[2] ' Catalogue of Western Scottish Fossils,' *Brit. Assoc. Handbook*, 1876, p. 32 ; ' Geology and Palæontology of the Clyde Drainage Area,' *Brit. Assoc. Handbook*, 1901, reissued 1904, pp. 465, 466 ; ' Explanation of Sheet 23,' *Mem. Geol. Surv.*, 1873, pp. 18, 24 ; ' Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, pp. 11, 12 ; etc.

[3] ' Geology of Central and Western Fife,' *Mem. Geol. Surv.*, 1900, pp. 39, 50 ; " Geology of East Fife," *Mem. Geol. Surv.*, 1902, p.71.

[4] J. Neilson, ' Notes on the Geological Survey Memoir,' *Trans. Geol. Soc. Glasg.*, vol. xiv., part iii., 1913, pp. 324-327 ; below, pp. 122, 132.

[5] B. N. Peach and J. Horne, ' The Canonbie Coalfield,' *Trans. Roy. Soc. Edin.*, vol. xl., 1905, p. 871 (issued separately, 1903).

[6] ' Geology of East Fife,' *op. cit.*, pp. 70, 71, 87, 102-105 ; Peach and Horne, *op. cit.*, p. 873 (encrinite-bed).

[7] ' Geology of Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, pp. 49, 79 (Wardie Shales) ; " Geology of East Fife," *op. cit.*, p. 71.

[8] ' Oil-Shales of the Lothians,' *Mem. Geol. Surv.*, 2nd edition, 1912, pp. 11, 17, and plate ii., column 1.

[9] *Ibid.*, p. 93 ; R. G. Carruthers, *Trans. Geol. Soc. Glasg.*, vol. xv., part ii., 1915, pp. 161-164 ; ' Economic Geology of the Central Coalfield of Scotland,' Area VIII., *Mem. Geol. Surv.*, 1917, p. 10 ; *ibid.*, Area IX., 1921, pp. 18-23 ; *ibid.*, Area VI., 1924, pp. 5, 8, 9.

If in view of these considerations it be admitted that the term Calciferous Sandstone must stand, then it can scarcely be doubted that the Hurlet boundary is both the most convenient and the most suitable. In addition to the fact that it has been in long use as the chief datum-line in the western Central Coalfield, and has been adopted in all recent Survey publications, the Hurlet marks an important epoch in Scottish Carboniferous history. Prior to this time, deposition proceeded in more or less detached basins or arms of the sea, separated by land-surfaces of Calciferous lavas or older rocks. Such barriers existed south-east of Carmunnock, between Hurlet and East Kilbride; near Lochwinnoch, between Renfrewshire and Ayrshire; also between Douglas and the main Lanarkshire coalfield, between Strathaven and the Lothian shale-fields, and elsewhere. The character of the sedimentation was accordingly much influenced by local conditions; correlations are correspondingly difficult and subject to dispute, and are complicated by signs of unconformity (p. 20), and by variations in the nature of the chief horizons—one bed apparently changing laterally from a fresh-water to a marine deposit (p. 19). As time progressed, the land barriers were submerged one by one; connection was established between Strathaven and the Lothians before the highest oil-shales were laid down, while the Carmunnock barrier persisted until immediately before the deposition of the Hurlet Limestone. From this moment onward, however, the physiographical conditions were very different. Throughout the Central Valley of Scotland, excepting parts of Ayrshire and Dumfries,[1] the land barriers of older rocks were now for the first time completely covered by the Carboniferous sea. The beds of volcanic detritus (p. 16), which mark the local base of the sediments where they rest on the lavas, cease at this period, and with them the last traces of variegated colouration, derived from the same source, disappear from the off-shore deposits; a new and widespread type of sedimentation supervenes (p. 34), so that correlation becomes a matter of comparative certainty. Dr. Kidston has shown[2] that a change in the land flora occurs at about the same time, and near East Kilbride the older flora is known to have persisted up to a horizon (the Basket Shell-Bed) only 13 fms. below the Main (Hurlet) Limestone.[3]

In fine, while "all the evidence is indicative of a gradual faunal change, due partly to migration, partly to evolution . . . from the marine fauna of the Liddisdale Cementstones up to the Millstone Grit, it would be manifestly impossible to construct an intelligible map on such uncertain data." "A line must be drawn somewhere, in order to bring out the geological structure on the map: the selection of any other position [than the Hurlet] would be less scientific, less important economically, and, relatively, purely local in character."[4]

R. G. C., C. H. D.

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[1] The evidence is against the supposition that Auchenheath, near Lesmahagow, forms another exception, as was formerly supposed. The Ayrshire case is stated by J. E. Richey in *Trans. Geol. Soc. Glasg.*, vol. xvii., part ii., 1925, pp. 204-232.

[2] *Proc. Roy. Phys. Soc. Edin.*, vol. xii., 1894, p. 224.

[3] 'Economic Geology of the Central Coalfield,' Area VIII., 1917, pp. 5, 10-12; Summary of Progress for 1910, 1911, pp. 65-67.

[4] 'Economic Geology of the Central Coalfield,' Area IV., 1920, p. 30.

The basal volcanic detritus.—Although each of the districts in the Glasgow area in which this group appears has its own type of sedimentation, they possess in common a basal bed made up of comminuted volcanic matter (only found at one point in the Campsie District), which rests on the underlying lavas, and is now regarded as of detrital origin, pointing to a period of subaerial erosion. This deposit is of a very characteristic nature; it is composed of variegated marls, red, chocolate, green or yellow in colour, intermingled with irregular courses of conglomerate, made up of pebbles of volcanic rocks, many of them well rounded. Similar deposits have been recognized at intervals throughout the Central Valley of Scotland. They have been mapped sometimes as a true volcanic ash, and sometimes as a detrital accumulation resulting from the wash of the exposed portion of the volcanic plateau. Sir Archibald Geikie, in his writings, is equally ambiguous, accepting the local mapping of the Geological Survey as the basis of his description. The latest author to deal with the subject is Mr. Barrow, who[1] considers beds of this nature, which succeed the Garleton Hill trachytes of East Lothian, to be detrital, and not truly volcanic, in origin. This view is adopted in the present case, for the following reasons:—

(1) The pebbles of volcanic rock are often water-worn, and are mixed with a large proportion of mica flakes and quartz grains that are evidently derived from a non-volcanic source.

(2) The deposit interleaves with the normal sediments above, although these sediments are on very different horizons in various localities.

(3) The wide geographical distribution of the deposit contrasts strongly with that of any ash bed actually interbedded in the lavas of the Clyde Plateau.

(4) Normal sedimentary intercalations among the lavas of the plateau are extremely rare, from which it would appear that the volcanoes stood up above the area of sedimentation. Accordingly it is but natural to expect that fringing detrital deposits would intervene in many places between the volcanic rocks and the sediments which finally overlapped upon the plateau, and smothered up the irregularities of its surface.

It should be noted that while the volcanic conglomerates are only present in the basal beds, formed on the local coast-line, the finer products of the erosion of the lavas were at the same time frequently washed out to sea and deposited off-shore, and now appear at intervals among the normal sediments in the form of variegated marls, or of colouration in fireclays and shales. Intercalations of this nature are especially common in the Paisley and Hurlet district. R. G. C., C. B. C., E. B. B.

Thickness of the Group.—Just beyond the western margin of the map, beneath the town of Paisley, the Hurlet Limestone lies about 180 fms. above the lavas. Still further west, near Howwood, the Hurlet Coal rests directly on them, so that the group is entirely absent[2]; much the same occurs at Thorntonhall, near East Kilbride and just south of the map.[3] In Campsie, the Tarfin bore (p. 27) penetrated to about 520 ft. below the Campsie Main (Hurlet) Coal without reaching the lavas; and further west the base of the Craigmaddie Sandstones is probably about 700 ft. or more below the same horizon (pp. 23, 28).

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[1] 'Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, pp. 81, 82.

[2] 'Economic Geology of the Central Coalfield,' Area IV., 1920, p. 6.

[3] *Ibid.*, Area VIII., 1917, p. 13.

In the Kilpatrick district, west of Milngavie, probably no less than 400 ft. of the group are exposed, but the full amount has not been proved. The Corrie Burn section is not easily measured, but at least 100 ft. of strata are visible below the equivalent of the Hurlet Limestone.

The basal overlap.—The recognition of the detrital nature of the beds of volcanic matter, both at the bottom of the group, and scattered through the overlying sediments, together with the evidence just brought forward of the great variations in the thickness of strata between the Clyde Plateau lavas and the Hurlet Limestone, demonstrate an important overlap at the base of the Upper Sedimentary Group of the Calciferous Sandstone. Prolonged denudation of the lavas must have been in progress in the Glasgow Area during at least part of the period when the Oil-Shale Group—3000 to 4000 ft. thick—was being deposited in the Lothians, though it is not possible at present to estimate the thickness of lava thus removed. Within the Group itself, on the other hand, though there are signs of discordance of small extent (pp. 20, 25), and the manner in which the lower strata of the Hurlet district pass into the Craigmaddie Sandstones is quite unknown, none of the available evidence can be regarded as pointing to the existence of any important unconformity.[1]

Progress of stratigraphical investigation.—While the Hurlet Limestone and Coal were for a long period the lowest seams whose position in the rock sequence was thoroughly known to mining engineers, the Hollybush Limestone was recognized as a lower horizon by R. L. Jack, at the time of the original survey, and was so shown on the one-inch map Sheet 30 (1878). Exposures of the Gallowhill and Dykebar Limestones were known, but the seams were unnamed and their horizons were not definitely determined till the revision of the ground by Mr. R. G. Carruthers.[2] Fossiliferous horizons below the Hurlet Limestone in the Campsie district were described by Dr. John Young in 1861, but their relative stratigraphical positions were not fixed (p. 23). Correlation between the Calciferous beds of the Hurlet and Campsie districts was extended to the Blackbyre and Baldernock Limestones in the first edition of this memoir, and further additions to, and modifications of, previous stratigraphy throughout the Glasgow Area have resulted from more recent work by members of the Survey[3] and by other observers, in particular Messrs. Macnair and Conacher.[4]

In spite of this advance upon our previous knowledge, correlation between the chief Calciferous horizons in the different parts of the Glasgow Area is, for reasons already indicated (p. 15), by no means easy. The limestones at present identified with the Baldernock, Blackbyre, and Hollybush appear to exhibit very considerable differences in the several districts, and signs of local unconformity have been detected by more than one observer (p. 20). It has accordingly been deemed advisable in the following paragraphs to adopt a strictly local nomenclature for the various seams: their current correlations can then be discussed without confusing the questions at issue.[1] Further, for greater clearness, the usual order of description will be inverted, and the strata dealt with from above downwards, since the Hurlet Seam, at the base of the overlying Series, may be regarded as the lowest horizon definitely identifiable in all parts of the Area.

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[1] *See* p. 18, footnote 2, for reference to a divergent view.

[2] Summary of Progress for 1905, 1906, p. 125; Do. for 1913, 1914, p. 71; First edition of this memoir, 1911, p. 18.

[3] R. G. Carruthers and J. E. Richey, 'The Lower Limestones of Renfrewshire and North Ayrshire,' *Trans. Geol. Soc. Glasg.*, vol. xv., part ii, 1915, pp. 249-264.

[4] P. Macnair and H. R. J. Conacher, 'The Stratigraphy of the Limestones lying immediately above the Calciferous Lavas in the Glasgow District,' *ibid.*, vol. xv., part i., 1914, pp. 37-50; P. Macnair, 'The Hurlet Sequence in North Ayrshire,' *ibid.*, vol. xv., part ii., 1915, pp. 206-220; *id.*, 'The Hurlet Sequence in the East of Scotland. . . ,' *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917, pp. 177-187.

(*a*) *Hurlet and East Paisley District.*

The average section in this part of the Area is as follows[2]:

		Fms.	Ft.	In.
[Hurlet Coal]		—	—	—
Blaes and fireclay, 0 to 18 ft.		1	3	—
WHITE LIMESTONE (Baldernock)		—	3	—
Marls, on blaes with sandstone bands, 4 to 7 fms.		5	3	—
BLACKBYRE LIMESTONE, 1 to 4 or more ft.		—	3	—
Blaes, with foul Coal 1 to 2 ft. at base		—	3	—
Sandstone with some fireclay		10	3	—
LADY ANN COAL, 6 to 15 in., in blaes		—	4	—
Sandstone		7	—	—
HOLLYBUSH LIMESTONE	Blaes with thin limestone ribs	2	—	—
	Limestone, 2 to 4 ft.	—	3	—
	Limy blaes	—	2	—
Coal, 6 to 18 in.		—	1	—
Sandstones, fireclays and blaes		5	—	—
SANDHOLES COAL, 8 to 24 in.		—	1	—
Dykebar Marls		20	—	—
Ferguslie Fireclay		1	—	—
Sandstone, with fakes and blaes		5	—	—
DYKEBAR LIMESTONE, 1 to 2 ft.		—	1	6
Strata, in upper part chiefly sandstones, with Castlehead and Newton Coals and some fireclays, and in lower part volcanic detritus, 95 to 135 fms.		115	—	—
[Lavas]		—	—	—

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[1] *Cf.* Dr Horne's suggestion in *Trans. Geol. Soc. Glasg.*, vol. xv., p. 112.

[2] *See* also Fig. 2. For a more detailed account of the Paisley district, *see* 'Economic Geology of the Central Coalfield,' Area IV., 1920, pp. 5-28.

A different version of the sequence of strata in the Calciferous Sandstone of Paisley has been propounded by Mr. D. Ferguson (*Proc. Geol. Assoc.*, vol. xxvi., pp. 191, 192; *Trans. Inst. Min. Eng.*, vol. lii., 1916-1917, pp. 7-32; *ibid.*, vol. lxv., 1923, pp. 260-292).

According to Mr. Ferguson:—(1) three "Gleniffer" Limestones (exposed near Limecraigs or Nethercraigs, not far from the Gleniffer Burn, 2 m. S. of Paisley) belong to a stratigraphical horizon, which, near Paisley, lies 166 fms. below the Hurlet Coal, and 180 fms. above the lavas; (2) a widespread unconformity, extending as far as Corrie (p. 44, footnote), separates the Gleniffer Limestones from the Hollybush and higher seams. Mr. Ferguson's arguments cannot be discussed here; but it may be pointed out that: (1) other observers correlate the three Gleniffer Limestones with the Hurlet, Blackbyre and Hollybush respectively on various grounds, in particular because (*a*) the Dykebar Limestone, which dips below the Hollybush at Dykebar is found with the same characters dipping below the lowest limestone of Gleniffer; (*b*) the fauna of the three limestones at Gleniffer agrees with that of the three seams named above, that of the lowest Gleniffer limestone showing an especially strong likeness to the Hollybush; (*c*) no limestone bearing any resemblance to the Gleniffer seams has ever been reached in any bore known to start above the Hollybush; (*d*) Mr. Ferguson's assumption that the limestone at the top of the Caledonia fireclay pit, near Paisley race-course, is the lowest Gleniffer seam (and, therefore, about 166 fms. below the Hurlet Coal), is definitely contradicted by the mining evidence as set out in the memoir on Area IV. (quoted above), Plate VI; (2) no good evidence is produced in favour of an extensive unconformity: the discordance exposed in the railway cutting and referred to by Mr. Ferguson (1923, p. 272, and Plate iii., Fig. 5) is probably no more than local, while elsewhere the unconformity postulated by him is more satisfactorily explained by simple faulting.

The *White Limestone*, which lies close beneath the Hurlet Coal, is a greenish or cream-coloured nodular impure limestone, often with fireclay partings. To the west of Paisley it contains Productids and even corals (*Syringopora*), but throughout the Glasgow Area appears to be of an estuarine nature with rootlets, fish-teeth, *Spirorbis* and *Carbonia*, thus resembling the Baldernock Limestone of the Campsie district, with which it may confidently be correlated.

The only exposures now visible in the district are: (1) in Arkleston railway cutting, N.E. of Paisley: dark impure bedded entomostracan limestone, passing down into greenish muds with nodular rootlety cementstones, the whole separated from the Hurlet Coal by 7 to 18 ft. of blaes and fireclay; (2) west of Old Crookston, Hurlet, beneath the whinstone escarpment. Ten inches of a similar limestone were exposed in 1905 in the foundations for Renfrewshire Poorhouses,[1] N.E. of Old Crookston. The hollow S. of Jenny's Well and immediately west of the whinstone sill, near Blackhall, Paisley, marks the site of a quarry in which was wrought a limestone, reported to have had no coal beneath it, and to have been of good quality. Blocks lying about in the quarry contain shale flakes but no marine fossils. It would seem from these facts that the White Limestone must have been wrought here.[2]

The *Blackbyre Limestone* is separated from the White by 4 to 7 fms. of strata, the upper half of which is usually marl or sandstone, the lower chiefly blaes. Its thickness as recorded in bores is about one or two feet of solid limestone, and a coal is nearly always found a foot or two below. Over the Hurlet district generally the seam is thin-bedded and flaggy, with partings of limy blaes; it contains abundant small brachiopods, usually much crushed, but gigantid *Productus* appears to be entirely absent; plant debris is not uncommon; corals are unknown in the type district and locality.

Exposures are: (1) In the railway cutting 200 yds. S. of Blackbyre, N. of Barrhead: 7 ft. of shaly limestone full of small brachiopods, overlying a mudstone with *Modiola lata*; near the top is a pure encrinital band 2 ft. thick. This is the type locality. (2) A small section, which may be seen by removing the turf, in the railway cutting, 500 yds. E. by S. of Blackhall, and about 130 yds. N.W. of the bridge: 2 ft. of flaggy limestone with encrinites and Producti on 4 in. of blaes with *Myalina* aff. *flemingi* and nests of *Actinopteria fluctuosa*, followed by a thin coal. The seam dips eastwards below the old quarry already referred to when describing the White Limestone; (3) Professor Macnair notices[3] an exposure of limestone above coal in the White Cart at Paisley, close to the swing bridge at Carlile Quay. The evidence of surrounding bores points to this being the Blackbyre seam.

In the old quarries south of the Arkleston Print Works on the estate of Gallowhill, Paisley, a flaggy calmy limestone containing 32 to 48 per cent. of $CaCO_3$, was formerly wrought. No section is now exposed, but at the more westerly opening the original surveyors in 1869 recorded "compact blue limy shales or cementstone with very small encrinites" dipping very gently to E.N.E. About 30 yds. to the north an old bore got: surface 93 inches, coarse limestone 27 inches, coal 6 inches, followed by 48 ft. of fireclay and sandstone. Taken in conjunction with the field evidence, this bore suggests that the limestone once wrought was the Blackbyre. Professor Macnair has made a detailed investigation into this question,[1] and concludes that the compact flaggy dark limestone with *Productus longispinus*, Rhynchonellids and encrinites, of which the wall west of the quarries is largely built, represents the typical Blackbyre Limestone, while other slabs in the same wall, which contain abundant *Lingula mytiloides* with fragments of phyllopod crustacea (*Dithyrocaris*, etc.), belong to a more estuarine phase of the Blackbyre, not at present known from any other locality, to which he gives the name Gallowhill Limestone. This estuarine phase is supposed to overlie the more thoroughly marine beds since, as Professor Macnair points out, the top of the Blackbyre Limestone is nowhere exposed in the type district, where the base of the seam shows nothing resembling the Gallowhill Limestone. There is some evidence that the Blackbyre was formerly exposed in the Arkleston cutting west of the bridge, but nothing can now be seen.[2]

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[1] 'Economic Geology of the Central Coalfield,' Area IV., 1920, pp. 48, 49.

[2] Prof. Macnair (*Trans. Geol. Soc. Glasg.*, vol. xvi., 1916, pp. 56, 57) inclines to believe that the Gallowhill Limestone, which he takes to represent the top of the Blackbyre (p. 20) was quarried here; it should be noted, however, that the *typical* Blackbyre, with the underlying coal, crops in the railway cutting some distance to the rise of, and at a lower level than, the old quarry; further, the blocks of *Lithostrotion* limestone which line the cutting where it crosses the hollow have no resemblance to the Blackbyre, either of that exposure or of the type locality, which so far as is at present known is quite devoid of corals (p. 20 and p. 20, footnote 4).

[3] *Ibid.*, p. 55.

Professor Macnair has correlated with the Blackbyre a limestone resting on volcanic detritus in the Levern Water, 1½ miles S.W. of Barrhead, which contains *Lithostrotion*, cup corals, and abundant *Productus giganteus*—a fauna very suggestive of the Hollybush. The position of the exposure is such that the identification with the Blackbyre certainly cannot be taken as established; and while at Bridge of Weir, 5 miles W. of Paisley, *Lithostrotion* has been found in the probable representative of the Blackbyre,[3] it has already been mentioned that neither corals nor large Productids are known from that seam in its type district, nor at Gallowhill, nor from its probable equivalent (p. 25) in Campsie. This fact should be particularly noted since accounts of the fauna of this horizon[4] often include species from seams whose correlation with the Blackbyre is by no means generally accepted.

The coal which underlies the Blackbyre Limestone is a thin but persistent seam, and is recorded in bores in which the limestone itself was not recognized. It varies from 5 to 18 or even 24 inches in thickness.

Evidence of some unconformity has been recorded at the top of the Blackbyre Limestone at Limecraigs (Nethercraigs),[5] and above its probable equivalent in Campsie.[6] While this discordance probably affects only a small vertical extent of strata, it may clearly introduce difficulties into the correlation of horizons lying close to each other. The general absence of the Gallowhill phase of the Blackbyre, the apparent change in character of the White Limestone west of Paisley (p. 19), the abnormality of the Corrie Burn sequence (p. 30), and other difficulties in the stratigraphy may all perhaps be connected with this phenomenon.[1]

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[1] *Ibid.*, pp. 46-60.

[2] *Ibid.*, pp. 53, 54, and vol. xv. p. 209.

[3] 'Economic Geology of the Central Coalfield,' Area IV., 1920, p. 17.

[4] *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917., pp. 180, 203; *Trans. Geol. Soc. Glasg.*, vol. xv., 1915, pp. 209, 218; *ibid.*, vol. xvi., 1916, p. 57 and pp. 290-304. The evidence of the blocks of *Lithostrotion* Limestone in the railway cutting near Blackhall (mentioned in these references) is very dubious; *see* p. 19, footnote 2.

[5] 'Economic Geology of the Central Coalfield,' Area IV., 1920, p. 16; *Trans. Geol. Soc. Glasg.*, vol. xv., 1915, p. 212; *ibid.*, vol xv., 1914, p. 39.

[6] *Trans. Geol. Soc. Glasg.*, vol. xv., 1914, pp. 44-46.

The strata between the Blackbyre and Hollybush Limestones consist mainly of sandstones with some fireclay, near the middle of which lies the *Lady Ann Coal*, wrought formerly in two pits near Blackbyre and Townhead (Barrhead) but not, it is believed, elsewhere in the Glasgow Area.[2] A limy kingle with vegetable remains and *Spirorbis*, formerly seen in the railway cutting 50 yds. N.E. of Blackhall, and shown on the one-inch map Sheet 30 (1878), probably belongs to this part of the sequence. The sandstone below the Lady Ann Coal outcrops frequently between Paisley and Barrhead, and has been quarried at Harelaw, Hollybush, Oldbarhills, and E.S.E. of Hawkhead; it is sometimes called the Hollybush Sandstone.

The *Hollybush Limestone*, a richly fossiliferous horizon throughout the district, is distinguished from the Blackbyre by the presence of giganteid and latissimoid *Productus*, and by the comparative abundance of simple and compound corals (*see* p. 121).

This seam is more or less well exposed at the following localities in the district: (1) Old quarries, somewhat overgrown, at Hollybush, 1½ mile N. by W. of Barrhead: limy blaes with bands of shelly limestone, above the main seam (now quarried out), contain the characteristic fauna.[3] A bore put down in the quarry in the overlying sandstone showed 14 ft. of limy blaes with irony ribs above the main limestone post (44 inches thick), followed by limy blaes 13 inches, coal 11 inches, fireclay and fakes 14 ft. (2) Near the south end of the reservoir within the policies of Hawkhead, ⅔ mile W.N.W. of Hurlet: 4 ft. of richly fossiliferous limestone (p. 121) are visible when the water is low, resting on a 14-inch coal. (3) South bank of railway cutting at Saucel Hill, ⅓ mile E. of Canal Station, Paisley. Here 5½ feet of limestone and limy blaes, with corals and large brachiopods, are separated from the underlying coal by a foot of papery blaes and alum shale containing *Lingula* and plants.[4] (4) On the hill above Brownside, 1 mile N.W. of Barrhead Station, 2 feet of the limestone are still exposed. Large Productids have been collected here.

The old quarries in the Hollybush Limestone, 150 yds. S.S.W. of Crosstobs, ⅓ mile W.S.W. of Blackbyre, are now quite overgrown. The usual large Productids have been found at Limecraigs, Westbrookhall (near North Brediland), Elderslie, Bridge of Weir,[5] and elsewhere south and west of Paisley; also in the limestone close to the top of the Caledonia Fireclay Works shaft, Paisley, where the underlying coal and fireclay were wrought. The Hollybush Limestone has further been proved in bores south of the Clyde from Barrhead and Paisley to Shieldhall and Renfrew.

Most of the 30 or 35 fms. of strata which come below the Hollybush is formed by the *Dykebar Marls*, consisting mainly of impalpable reddish marl, which crumbles rapidly on exposure to weathering and may at first be taken for volcanic tuffs; closer inspection, however, reveals the presence of minute flakes of muscovite, indicating their detrital origin, and they are no doubt one of the off-shore washes referred to on p. 16. Bands of kingle and harder limy marl (usually recorded in bores as limestones) occur at frequent intervals. Exposures occur in the Hawkhead Burn, 1 mile N.W. of Hurlet, and in the railway cutting E. of Paisley Canal Station; the best section is south of Paisley, in the Wardhouse Burn due S. of Nethercraigs Bleach Works.

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[1] *See* also pp. 17, 25.

[2] The "Lady Ann" Coal referred to as exposed near Glenfield Starch Works, Paisley (*Trans. Geol. Soc. Glasg.*, vol. ii., 1867, p. 169) is probably one of the Castlehead or other seams below the Hollybush.

[3] Macnair, *Trans. Geol. Soc. Glasg.*, vol. xv., 1915, p. 206.

[4] 'Economic Geology of the Central Coalfield,' Area IV., 1920, pp. 13, 14.

[5] *Ibid.*; also Macnair and Conacher, *Trans. Geol. Soc. Glasg.*, vol. xv., 1914, p. 41.

A foul coal (Sandholes Coal), with much fireclay, occurs on top of the Marls and 5 fms. below the Hollybush coal: beneath them, a few fathoms of sandstone intervening, lies the *Ferguslie Fireclay*, a 7 to 10 ft. seam of good quality, which has been much wrought near Paisley for the best sanitary ware.

The *Dykebar Limestone* was first recognized in the Hawkhead Burn on the N.E. side of Dykebar Station, and is well seen also 500 yds. further to south-east; the best exposure, however, is in the Wardhouse Burn, Nethercraigs, 2 miles S. of Paisley, just below the point where it first approaches the Harelaw Aqueduct. It is a dark, impure, bedded, distinctly irony limestone, with deep ochreous weathering, up to $2\frac{1}{2}$ ft. in thickness; a poor coal or black fireclay lies beneath. The limestone is full of Productids, with other small ribbed brachiopods, gasteropods, and lamellibranchs (including at all localities the rare *Leiopteria divisa* (M'Coy), found also low down in the Oil-Shale Group near Edinburgh, and in the Cementstones of Liddisdale).[1]

Some 60 or 70 fathoms of sandstones with coals separate the Dykebar Limestone from the volcanic detritus which overlies the lavas; the coals (Castlehead and Newton), are of poor quality, but have been wrought in the past around Paisley. The chief interest of these strata lies in the evidence which has been brought forward to show that they are contemporaneous with the Thick Coal of Quarrelton, 4 miles W.S.W. of Paisley—the thickest single accumulation of coaly matter in Britain—into which they pass laterally, by increase in the thickness of the individual seams and by attenuation of the intervening sediments, when traced towards the site of the old marshy tract in which that great mass of vegetable matter slowly accumulated.[2]

(*b*) *Campsie and Kilpatrick Districts.*

The rocks described under this heading outcrop in a broken belt extending from the Campsie Fault (p. 207), where it forms the southern boundary of the Campsie Fells, in a west-south-westerly direction through Milngavie, Douglas Muir, and Duntocher towards the River Clyde at Dalmuir, 3 miles N.W. of Renfrew. It will be found convenient to begin with the higher beds of the group, first in the Campsie district, to the east of Milngavie, and then in the Kilpatrick area, lying west of that place, and to postpone the description of the lower strata in both districts—the Craigmaddie Sandstones—to the end of the section.

Campsie District.—This region is divided by the valley of the R. Glazert into the "North Brae," lying N. and N.E. of Lennoxtown, and the "South Brae," which stretches westward towards Craigend and Craigmaddie Muirs, and slopes southward down to the haughs of the Kelvin. It has been a favourite collecting-ground for Glasgow geologists since the first publication by the late Dr. John Young of

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[1] The *Lithostrotion* recorded in the first edition of this memoir (p. 17) was from a loose block and has not been found in place.

[2] For full details of this interesting deposit *see* 'Economic Geology of the Central Coalfield,' Area IV., 1920, pp. 19-28.

"The Geology of the Campsie District."[1] In this work he distinguished four sets of fossiliferous beds below the Main Limestone, the following being, he at first considered, their most probable descending order: Balgrochan Beds, Millburn Beds, Balglass Burn Beds, Craigenglen Beds; he further suggested that the Balgrochan Beds might represent the Shelly [White] Limestone, and the Millburn Beds the *Productus giganteus* Limestone, of the south Lanarkshire coalfield.[2] In the latest edition the suggested descending order is: Craigenglen, Balglass Burn, Balgrochan Burn, and Mill Burn Series. These "Beds" or "Series" in general comprise several strata of which no measured details are given, and it is not always possible to identify the beds or even the exposures referred to; the Balgrochan and Craigenglen Beds can, however, be recognized, and are referred to in the sequel. The Millburn Beds appear to include both a fresh-water and a marine limestone[3]—probably the Baldernock and Balgrochan Beds respectively of the following pages. The Balglass Burn[4] fossils were collected from blocks of shale and nodules of ironstone lying in the bed of the burn; the exact spot cannot be identified, and it is impossible to discover whether these represent the Balgrochan Beds, the Craigenglen Beds (though from the fossil list this appears unlikely), or as believed by Young, another fossiliferous horizon.

The next publication to deal with this district in any detail was the first edition of this Memoir (1911), containing the results of the work of the late Dr. Crampton. These were partly confirmed and partly emended in the important paper by Messrs. Macnair and Conacher, to which frequent reference has already been made.[5]

The average sequence of rocks in the Campsie district is as follows (*see* also Fig. 2):—

	Fms.	Ft.	In.
[Main (Hurlet) Coal]	—	—	—
Fireclay, 6 to 18 in..	—	1	—
BALDERNOCK (WHITE) LIMESTONE, with kingle, 5 to 9 ft.	1	1	—
Blaes, 4 to 7 ft.	—	5	6
BALGROCHAN BEDS (limestones and limy blaes), 8 to 10 ft.	1	3	—
Thin Coal, 1 to 14 in.	—	—	7
Fireclays and kingles, on sandstone, with coal at base, 15 to 20 fms.	17	3	—
CRAIGENGLEN BEDS (blaes, limestone bands, clay-band ironstones), about	3	2	—
Thin Coal and fireclay, 0 to 18 in.	—	1	—
Sandstones, with blaes, fireclays, kingles and thin coals	30		
CRAIGMADDIE SANDSTONES, with thin fireclays and marls, and towards the base bands of quartz conglomerate, say	60	—	—
Volcanic detritus (generally absent in this district)	—	—	—
Lavas	—	—	—

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[1] *Trans. Geol. Soc. Glasg.*, vol. i., part i., 1st edition, 1860; 2nd edition, 1868; 3rd edition, 1893-4.

[2] *See* 'Economic Geology of the Central Coalfield of Scotland,' Area IX.; 1921, pp. 10-14 and Plate VI., col. 5.

[3] The correlation of the latter with the *P. giganteus* Limestone of south Lanarkshire rested on the discovery of a single imperfect specimen of that fossil, which however, has also been recorded from Craigenglen (p. **26**). The presence of corals in the same bed, though referred to in Young's text, is not substantiated in any of his fossil lists. *See* p. **25**, footnote **9**.

[4] Baldow Glen of the six-inch Maps. *See* p. **26**.

[5] *Trans. Geol. Soc. Glasg.*, vol. xv., part i., 1914, pp. 37-50.

Owing to the pale cream colour which it assumes after exposure to the weather, the *Baldernock Limestone* was long known in this district as the White Limestone, in contradistinction from the blue (Main) and black (Blackhall) seams.[1] Being impure and locally somewhat dolomitic it was not wrought to any great extent: the chief workings seem to have been to the north of Glorat Ho. Analysis showed the following percentages: $CaCO_3$ 83·20, $FeCO_3$ 2·17, $MgCO_3$ and moisture 2·63, Iron pyrites 0·13, Insoluble earthy matter 11·87. This limestone is separated from the Main (Hurlet) Coal above it by 6 to 18 inches of fireclay, and thus corresponds in position to the White Limestone of Hurlet; it also resembles that seam in character, being marked by an abundance of fresh-water entomostraca (*Carbonia fabulina*), with plant, fish, and indeterminate shelly remains, but shows no trace of the thoroughly marine phase which the corresponding bed assumes in the country west of Paisley (p. 19). The seam is 3 to 5 ft. thick, locally subdivided by thin beds of fireclay or blaes, and generally passes down into a kingle with rootlets.

Exposures on the South Brae are: (1) at Linn of Baldernock (the name locality), ⅔ mile E.S.E. of North Blochairn, when the section is complicated by the overlying dolerite intrusion; (2) Blairskaith Muir, ⅔ mile W.N.W. of Newlands; (3) Barraston Burn,[2] E. by N. of the site of South Craigend steading and ½ mile S.W. of Newlands, and again 200 yds. lower down the burn; (4) Glenwynd (the upper part of the Red Burn), ⅓ mile S. by E. of Newlands: the kingle at the base contains rootlets and *Spirorbis*;[3] (5) Muirhead Glen, 150 yds. N.W. of Finniescroft steading and 500 yds. E.N.E. of Muirhead; (6) Baldow Glen, 400 yds. S.W. of Baldow House. On the North Brae there are exposures: (7) in Burnel Rannie, at lane 100 yds. above Balgrochan steading and W. of waterworks, ½ mile N. of the Campsie Parish Church in Lennoxtown; (8) at old Bencloich mill dam, 400 yds. due E. of the same church:[4] this exposure was correlated with that at locality (3) as well as with those at (7) and (9) by the late R. L. Jack; (9) Sloughneagh Burn (descending from the long north-running felsite dyke crossing Lairs Hill), just below pond 350 yds. E. of Bencloich Mains, and ⅔ mile E.N.E. of the church.

Some 4 to 7 ft. of dark blaes with *Lingula* and plant remains[5] separate the Baldernock from a set of thin limestones, alternating with limy blaes, which is seen at several localities in the district. Since there can be no doubt that (at locality No. 7 below) these are the strata referred to by Dr. John Young as "*Balgrochan Beds*," his name has a prior claim and will be adopted in the following paragraphs.[6] At the same time the identification of this horizon with the Blackbyre of the Hurlet district, put forward in the first edition of this memoir[1] and agreed to by later observers, is almost certainly correct, in view of the stratigraphical position of the beds relative to the Hurlet Seam, and of their resemblance to the Blackbyre Limestone of the type localities: the older, local, name is reintroduced chiefly in order to avoid prejudice to discussions of correlation with other districts, as mentioned on p. 18. It may be noted that this correlation between districts some twelve miles apart tends to show that the unconformity noticed in places at the top of the Balgrochan Beds, and of the Blackbyre Limestone,[2] is unlikely to be of any great vertical extent.

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[1] 'Statistical Account of Scotland,' vol. xv., 1795, p. 329; 'New Stat. Account,' vol. viii., 1895, Stirlingshire, pp. 240-242.

[2] This stream rises ½ m. W. of Newlands, and runs S., E. by S., S.W., S., E. by S. towards Barraston Farm (close to 317-ft. level) into the alluvium N. of Hillhead.

[3] Macnair and Conacher, *op. cit.*, p. 44.

[4] Abundant *Carbonia fabulina*, with *Spirorbis*, plants and fish remains, occur here (Millburn, *see* p. 25, note 9) in dirty-yellow "fresh-water" limestone. *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, pp. 222, 223.

[5] Macnair and Conacher, *op. cit.*, p. 45.

[6] These beds are the "highly fossiliferous shales," correlated with the Blackbyre Limestone, of the first edition of this memoir, pp. 15-17, and the "Glenwynd Beds" of Messrs. Macnair and Conacher, *op. cit.*, pp. 44, 46.

As described by Dr. Young, the Balgrochan Beds are composed of limestones[3] (made up of a vast accumulation of ill-preserved shells, especially brachiopods, cemented with dark grey clay), along with limy blaes, the upper parts of which have yielded polyzoa, and the lower clay-ironstones which contain very perfect Athyrids and *Rhynchonella*. The fauna shows few distinctive features other than the absence or rarity of the large Productids and corals which characterize the Craigenglen Beds—points in which it compares well with the typical Blackbyre exposures (p. 19).

The Balgrochan Beds are seen at most of the localities where the Baldernock Limestone is exposed; in the following list the locality numbers are the same as those given under the latter seam on p. 24, the type exposure of Dr. Young being No. 7:—(1) the section is much disturbed by the intrusion;[4] (3) E. by S. of South Craigend, 150 yds. downstream from the higher exposure of the Baldernock Limestone and 25 yds. above the cattle ford; (4) 6 to 12 inches of hard limy blaes, or limestone of Pendleside type, with Goniatites, lamellibranchs, *Productus* and plants,[5] rest on a 12-inch encrinital limestone overlying 2 to 4 ft. of soft shelly blaes with crushed brachiopods but no corals; (5) it seems to have been at this point that the 10-inch marine limestone overlying a 14-inch coal, parroty at the top, stated to have cropped out on the slope of the South Brae, down towards the River Glazert,[6] was once seen; (6) 9 ft. of limy shales full of small Productids with at least two encrinital limestone bands[7]; (7) the "Balgrochan Burn," viz., Burnel Rannie, 50 yds. above Balgrochan steading — the type locality[8] of the Balgrochan Beds as described by Dr. Young: 9 ft. of limy blaes with limestone bands; (8) 50 yds. below the old dam;[9]

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[1] Though first made by Dr. R. L. Jack. *See* footnote 7 below.

[2] Macnair and Conacher, *op. cit.*, pp. 39, 44-46; 'Economic Geology of Central Coalfield,' Area IV., 1920, p. 16. *See* above, p. 20.

[3] One being 4 ft. thick, *Geologist*, vol. iii., 1860, p. 16.

[4] Macnair and Conacher, *op. cit.*, p. 45; *Trans. Geol. Soc. Glasg.*, vol. xv., p. 116.

[5] Compare a similar bed containing *Posidonomya becheri* at the base of a limestone, probably the Blackbyre, in the River Gryfe, near Bridge of Weir, 'Economic Geology of the Central Coalfield,' Area IV., 1920, p. 17.

[6] 'New Statistical Account,' *op. cit.*, pp. 241, 242, items Nos. 15-19; and Young, *op. cit.*, 1860, p. 37, 1893, p. 55.

[7] Macnair and Conacher, *op. cit.*, p. 46, item *d*; one of these bands, a 2 ft. dark impure limestone with tiny *Lingula*, was correlated by R. L. Jack, the original surveyor, with a similar band [in the Blackbyre Limestone] at Arkleston, near Paisley (*see* p. 20).

[8] 'Explanation of Sheet 31,' 1879, locality 144, pp. 61, 64; Young remarks that encrinites are rare at this locality, but they appear to be common elsewhere.

[9] *Ibid.*, locality 140, pp. 61, 65 (*not* 66). The Millburn Beds of Young appear to be the Balgrochan Beds, together with the Baldernock Limestone, of locality (8), possibly also of locality (9). See p. 23. This exposure is now obliterated by diversion of the stream.

soft grey blaes with bands of earthy limestone; (9) 30 yds. below the pond: a 10-inch earthy shelly limestone resting on dark blaes; (10) 120 yds. S.S.E. of the preceding locality, in the south bank of a hollow in mid field: 3 ft. of flaggy shelly limestone resting on 6 in. of limy shelly blaes.

The thin coal, once seen at locality (5), appears to be nowhere exposed at the present time; it corresponds to the coal below the Blackbyre Limestone of Hurlet (pp. 19, 20).

The Balgrochan Beds are followed in downward succession by fireclays and kingles, below which a thick sandstone is observed in the stream sections around the South Brae, and 100 yds. W. of the parish church. A thin coal, reaching 18 inches near Glenwynd, occurs near the base of the sandstone under which, and 15 to 20 fms. below the Balgrochan Beds, are found some 20 ft. of dark blaes. These are the *Craigenglen Beds* of Messrs. Macnair and Conacher.[1] They contain bands and nodules of clay ironstone, formerly mined and wrought opencast in the banks of the Craigenglen Burn, along with beds of limy blaes with lenticles of encrinital limestone, and are locally very rich in well-preserved fossils, gastropods being, according to Young, more numerous than in any other beds in the Campsie district. The presence of giganteid and latissimoid *Productus*. with *Lithostrotion* and other corals, and the known stratigraphical position of these beds, renders their correlation with the Hollybush Limestone of Hurlet and Paisley, first propounded by Messrs. Macnair and Conacher, highly probable; but for reasons already referred to the retention of a local name is considered advisable.

The chief localities are:—(1) The type section in lower Glenwhapple, near the ruins of Craigenglen cottage, situated 300 yds. S.S.E. of Upper Carlstoun steading, 1½ mile S.S.W. of the parish church in Lennoxtown[2]: some 20 ft. of blaes, with limestones and ironstones, intervene between sandstones with thin coals: the clearest exposure is N.W. of the ruins, but the beds also occur S.W.; (2) in Glenwynd, 150 yds. below the ruins of the cottage: beneath 18 inches of burnt coal and 3 ft. of kingle sandstone, 6 ft. of blaes with ironstones rest on ribs of grey limestone with blaes partings, containing Rhynchonellids and corals; (3) according to Young the same beds were once exposed fully half a mile to the west, probably near South Craigend; (4) Baldow Glen, 200 yds. W.S.W. of Baldow House, and about 130 yds. S. of the lane: below thick sandstone an incomplete section shows two encrinital limestones above blaes with *Productus latissimus* and corals. A poor, thin coal below, resting on fireclay and sandstone, is a further feature in which this resembles the type section, and may be compared with the Hollybush Coal. Old crop workings, now quite obliterated, extend for ⅓ mile eastward from this point, but it is not clear whether limestone or ironstone was sought; (5) At Baldernock Mill, 250 yds. N.N.E. of Dowan, 1 mile E. of Milngavie, is an exposure of at most 13 ft. of limy blaes with impure limestone bands. The poorly-preserved fossils are mainly small brachiopods, especially Rhynchonellids, with *Lingula*, goniatites, and lamellibranchs. *Productus giganteus* is found, though rare, and suggests that these are part of the Craigenglen Beds, as believed by Macnair and Conacher.[1]

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[1] *Op. cit.*, pp. 44-47. J. Young, *op. cit.*, 1st edition, pp. 21, 22, 39-45, 3rd edition, pp. 38, 39, 61-72, included under this name not only the beds under description, but also sandstones, shales and entomostracan limestones, whose relative positions are not clearly set out, and may lie higher in the sequence. In view of the supposed faulting down of the Blackhall Limestone at the mouth of the glen (Macnair and Conacher, p. 47; first edition of this memoir, p. 22, *see* also p. 42, note 5), and the possibility that the overlying Neilson Shell-bed was once exposed, lists of 'Craigenglen' fossils must not be regarded as derived from the Craigenglen Beds, unless the position in the section from which they were collected is clearly stated. In the first edition of this memoir, p. 22, and on the special one-inch Map, these Beds appear to have been regarded as belonging to the neighbourhood of the Blackhall Limestone, brought down by the Langshot east-and-west fault which skirts the southern slope of the South Brae.

[2] 'Explanation of Sheet 31,' 1879, localities 135, 136 and 148, pp. 61, 64, 65 (where for 236 and 248 read 136, 148).

The strata which follow below the Craigenglen Beds are partly exposed around Clochcore, S. of Lennox Castle, and have been bored through at Glorat, at and near the Campsie Alum Works, and at Tarfin, 600 yds. E.N.E. of Muirhead. These old bores show thin coals, with fireclays and blaes, and sometimes limy bands (probably not true limestones), down to 30 fms. below the Craigenglen position, beyond which point the Tarfin bore penetrated 200 ft. of sandstone, with very thin fireclays, forming the upper portion of the Craigmaddie Sandstones described in a later paragraph. No representative of the Dykebar Limestone of Paisley is at present known in Campsie.

Kilpatrick District.—Eight miles west-south-west of Lennoxtown, the upper part of this Group of rocks is met with to the south-west of Douglas Muir, at and just beyond the western margin of the map. Very little is known about the sequence in this district, and no record appears to exist of the presence or nature of the Baldernock Limestone.

The first known horizon below the Hurlet Coal is a white sandstone probably several fathoms thick. Some 20 ft. are seen in the Duntocher Burn, 350 yds. S.E. of Auchentoshan Ho., resting directly on 10 ft. of limy blaes, with limestone ribs, containing gigantid *Productus* and corals. Calcareous beds with a similar fauna are exposed in Duntocher Burn S. of William Street, at the entrance to the old sandstone quarry near the hospital at Hardgate, and in the stream 200 yds. S.W. of Lawmuir; they were also found in drains at the bend of the road, 250 yds. N. of the same farm, and on the north side of the hospital. The limy strata are succeeded downwards by a hard thin sandstone resting on a foul coal which is 18 inches thick at Auchentoshan, and 14 inches north of the hospital where it was worked along the outcrop. The fossiliferous horizon, regarded in the first edition of this memoir as equivalent to the *Productus* shales (Balgrochan Beds) of Campsie, was later correlated with the Craigenglen Beds (Hollybush) by Messrs. Macnair and Conacher,[2] and in view of their palæontological character, this identification must be regarded as highly probable. There thus appears to be no exposure of the Balgrochan Beds (Blackbyre) in this district, nor is any bore known which passes down below the Hurlet Coal through their presumed position.

The coal just described is followed downwards by sandstones, which outcrop on the south side of the streamlet which flows along the north side of Hardgate; below them another coal 18 to 21 inch thick has been proved in bores at Hardgate, and was formerly exposed 330 yds. due E. of Law steading. About 300 yds. W. of the same farm a limestone, apparently at a lower horizon, was once found in drains. Below the last-mentioned bed the strata consist, so far as is known, chiefly of white sandstones with coarse and conglomeratic bands, well exposed in the Cochno Burn north of Faifley, among which a 5-foot fireclay, with a coaly layer on top, was once mined at the side of the stream. These are the Craigmaddie Sandstones next to be described.

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[1] *Op. cit.*, p. 50.

[2] *Op. cit.*, p. 50.

Craigmaddie Sandstones.—In both the Campsie and Kilpatrick districts the lower portion of the Group consists of a mass of sandstones and conglomerates, probably 300 to 400 ft. in thickness, resting upon the lavas. The actual junction of the sediments with the lavas is not exposed, and is faulted out for considerable distances.

On the west side of Douglas Muir a basal bed of volcanic detritus has been mapped, but elsewhere has not been found. It may be absent round Craigmaddie and Craigend Muirs, where the lowest bed seen is a quartzose conglomerate[1] which is free from volcanic material, although it can be traced up to a few feet from the lava outcrop. The overlying beds consist largely of conglomeratic and gritty sandstone with small pebbles of milky quartz. These beds form the barren uplands of Craigmaddie, Craigend and Douglas Muirs. In the latter district, in the streams south of Crossburn, a bed of variegated marl can be seen amongst the grits : in other parts of the district, however, both the quartzose conglomerates and the sandstones are remarkably free from volcanic material.

These gritty beds pass up into sandstones of a finer texture, which are largely quarried for building-stone near Craigmaddie Reservoir ; they are interleaved with thick beds of fireclay and kingle bands. One of the rare volcanic-detritus beds—a 6-foot red ashy fireclay—is seen among these higher strata in the burn just N. of Clochcore, S. of Lennox Castle.

(*c*) *Corrie District.*

The difficulties of correlation between the different districts in which this Group is exposed, referred to on a previous page, are nowhere better exemplified than at Corrie. Dr. Young, at first inclined to place all the Corrie rocks higher than anything in Campsie (including the "Black" [Blackhall] Limestone, and at one time even the Balquarhage [Calmy] Beds), at a later period considered that they corresponded as a whole to the Campsie Main Limestone, or to beds still lower in the sequence.[2] The identification of the blue (Corrie Burn) limestone of Westside with the Campsie Main or Hurlet Seam (p. 44), now scarcely disputed, throws the rocks about to be described into the Upper Sedimentary Group of the Calciferous Sandstone, but the correlation of the different beds with those of the same group even at Campsie, only three miles away, is by no means agreed on (*see* below).

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[1] An interesting feature of secondary origin has been detected in regard to the pebbles of the conglomerate at the base of the Craigmaddie Muir sandstones. The pebbles are mainly of white vein-quartz, and are generally composite, consisting of parts of several crystals. Now, in a sandstone it is common to find that the sand grains have had silica deposited on them in crystalline continuity from circulating waters, and in this conglomerate precisely the same process has obtained in respect to the large quartz pebbles. The phenomenon was recognized in the field, for it was noticed that the surfaces of the pebbles exhibit a peculiar sheen, with a patchwork arrangement. Examined under the microscope by reflected light, the surfaces are found to carry numerous little facets which reflect simultaneously over definite areas. Careful examination shows that the same area may reflect light in several different directions, as several sets of parallel facets are present. These facets together form edges and quoins which are parts of positive crystals ; they are therefore due to growth, for had they been due to corrosion, they would have formed the sides of small cavities. Examination of sliced specimens shows, as was to be expected, that the secondary growths are in crystalline continuity with the original quartz crystals present in the pebbles.
G. W. G.

[2] *Op. cit.*, 1860, p. 29, 1893, p. 46 ; *Geologist*, vol. ii., 1859, pp. 468, 469.

The characteristic feature of the Corrie district is the great development of the volcanic detritus that rests upon the lavas at the base of the series, and the thinning out of the other sediments found below the Hurlet Limestone around Craigmaddie Muir (p. 28).

The section exposed in the Corrie Burn, about ½ mile W.S.W. of Corrie on the southern slope of the Kilsyth Hills, has long been familiar to Glasgow geologists. The base of this section is formed by the Campsie fault, which crosses the stream half a mile above the sharp bend to the south, and about the same distance north-west of Burnhead. Upturned against the fault is a hard unfossiliferous limestone, and above it a thin basalt lava of the Jedburgh type, also in a vertical position. Volcanic detritus and mud, with rolled volcanic fragments and occasional intercalations of impure sandstone, are exposed in the burn for ⅓ mile below the fault; these constitute the last item of the following table.

Young's accounts[1] of the sequence in the "western" (Corrie) Burn, and on the hillside above it, show that the greater part of his fossils were collected from the encrinital (Corrie Burn) limestone, still extensively wrought in 1860, and from the intercalated and overlying limy blaes. The coralline limestone he describes as 2 to 3 ft. thick, never much worked, and built up of the remains of corals, chiefly "*Lithodendron*" and often in the position of growth, the interstices between which are filled with greenish-grey slightly calcareous clay. This compares so well with the Coral Limestone of the following table that he must be regarded as referring to the same bed, although the only coal[2] mentioned in his section is distinctly placed below the coralline bed, whereas the only coal now visible is obviously *above* the Coral Limestone.

The section now to be seen in Corrie Burn is approximately :—[3]

	Ft.	In.
[Coal, ? Hurlet, p. 44]	—	—
Fireclay, black at top, soft and white below, with ironstone nodules, 6 to 24 in.	1	6
WHITE NODULAR LIMESTONE, full of rootlets at top, some encrinites and brachiopods at base, 1 to 3 ft.	2	—
CORAL LIMESTONE (*Lithostrotion irregulare*), inconstant, with irregular partings of pale greenish clay, 2 to 5 ft., passing down into	3	6
Pale limy blaes, with strings of limestone nodules, the upper part crowded with brachiopods (especially *Productus*, including *P. pugilis*, *P. punctatus*, *P. youngianus*,[4] and *Pugnax pleurodon*), corals (*Lithostrotion*, *Dibunophyllum*, *Zaphrentis*), bryozoa (Fenestellids, *Glauconome*, *Tabulipora*) and encrinites. This is the richest fossiliferous horizon at Corrie now exposed, ... about	6	6

[1] 'Geology of Campsie,' *op. cit.*, 1860, pp. 29, 30, and 1893, pp. 46-48.

[2] Said to be wrought for burning the lime. It would appear that the 6-in. coal now visible must have been locally much thicker, or it could scarcely have been worth the working. An old adit to the coal is seen, opening in strata below the Coral Limestone: this may have been the cause of Young's error. Bryce's figure ('Geology of Clydesdale and Arran,' 1859, p. 25) derived from Young (*ibid.*, p. v.) places the coal correctly.

[3] Compare the table given by Prof. Macnair, *Proc. Roy. Soc. Edin.*, vol. xxxvii, 1917, pp. 185, 186.

[4] The type specimens are recorded, however, as from *above* the Coral Limestone. (Davidson, *Monog. Brit. Carb. Brachiopoda*, 1862, p. 168.)

	Ft.	In.
Grey smooth-splitting blaes with *Actinopteria persulcata*, ferns, occasional goniatites, *Orthoceras*, *Sanguinolites abdenensis*, and eurypterid fragments	1	—
Blaes with nodules containing pectiniform lamellibranchs, and a band of *Naiadites crassa* at the base	1	—
Irony kingle with entomostraca and lamellibranchs	—	8
Blaes containing clayband ironstones, with *Naiadites crassa*, *Lingula*, and entomostraca	2	—
Fireclay	—	6
Purplish volcanic detritus	18	—
Cornstone 1 ft., on marly volcanic detritus	4	6
Sandstone on fakes	4	6
Blaes, mostly faky	16	—
Irony cement, with rootlets	1	—
Purplish volcanic detritus	5	—
Kingle sandstone	—	9
Purplish volcanic detritus, with bands of small lava pebbles, at least	30	—

The Coral Limestone of the preceding table has been regarded as equivalent to the Balgrochan Beds of Campsie, and to the Blackbyre Limestone of Hurlet, by the late Dr. Crampton[1] and by Professor Macnair;[2] it has also been considered to represent the Hollybush Limestone.[3] In the present state of our knowledge, however, it is preferable to compare the Corrie section with districts to the east and south, to which it shows a far greater resemblance than to the type district of Hurlet. The Coral Limestone, taken along with the richly fossiliferous blaes which immediately underlie it, presents a striking lithological and palæontological similarity to Limestone "E" of the upper Bannock Burn, seven miles to north-east;[4] and its general resemblance to the chief coral limestone at Aberlady, Dunbar and St. Monans, on the shores of the Firth of Forth, was pointed out by Dr. Crampton.[5] It may further be compared in many respects with the White Coral Limestone (the first below the Main) of Birkwood Burn near Lesmahagow.[6] In the type sequence of Hurlet, the seam which it most resembles is the Hollybush, from which, however, it differs notably in the absence of gigantid Producti: in fact while Limestone "G" in the Bannock Burn, and the *Productus giganteus* Limestone of Carluke are faunally quite like the Hollybush Limestone, there appears to be no bed at Corrie which can properly be compared with that seam, or with its probable Campsie equivalent the Craigenglen Beds. The outstanding objection to correlation of any part of the Coral Limestone with the Blackbyre, or with the Balgrochan beds, is the fact that corals are unknown from these horizons wherever definitely known within the limits of the Glasgow special map, and are not abundant in their probable equivalents to the west of Paisley.[7] Possibly the Coral Limestone may be equivalent to the White Limestone of Bridge of Weir and Howwood—apparently equivalent to the White (Baldernock ?) Limestones of Paisley and district—which contains *Syringopora* and small *Productus*,[1] but at present no confidence can be placed in any correlation with western areas ; indeed, a recent study of two white coral limestones at St. Monan's tends to show that the small unconformities with which beds of this nature are so often associated may render their accurate correlation impossible, unless the strata both above and below them can be identified with certainty in the districts between which a comparison is instituted.[2]

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[1] First edition of this memoir, pp. 19, 20 and p. 30, Fig. 2.

[2] Macnair, *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917, p. 186.

[3] Macnair and Conacher, *op. cit.*, 1915, p. 49.

[4] Summary of Progress for 1919, *Mem. Geol. Surv.*, 1920, pp. 36-40. "E" is the first limestone below the Murrayshall Limestone (the probable equivalent of the Hurlet). Dr. G. W. Lee remarks that the slabby limestone "F," close under "E," and containing a fauna of brachiopods, etc., with no distinctive character, may be a local facies of part of the fossiliferous beds under the Coral Limestone of Corrie.

[5] First edition of this memoir, p. 15; *Trans. Geol. Soc. Edin.*, vol. ix., 1910, p. 74.

[6] 'Economic Geology of the Central Coalfield,' Area IX., 1921, p. 43.

[7] *See* above, pp. 19, 20.

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[1] ' Economic Geology of the Central Coalfield,' Area IV., 1920, p. 18.

[2] D. Tait and James Wright, *Trans. Geol. Soc. Edin.*, vol. xi., part ii., 1923, pp. 165-184. In one case a lithological and faunal change is actually seen to occur within a distance of 100 yds., and takes place not by transition but by the over-lapping of the white, richly coralline type over the normal grey mainly encrinital type, with few corals. In the other case a similar replacement appears to occur between two exposures a mile apart. For another instance of apparent lateral change, *see* the difference between the Bannock Burn and Touchadam sections, in Summary of Progress for 1919, pp. 38-40.

CHAPTER IV.

CARBONIFEROUS (*continued*).—CARBONIFEROUS LIMESTONE SERIES.

The base of this division of the Carboniferous System, throughout this memoir and in the new edition (1924) of one-inch Sheet 31, is drawn at the bottom of the Hurlet Seam, for reasons which have already been indicated (p. 14). The Hurlet Seam for this purpose is considered to include the beds from the top of the Hurlet Limestone to the base of the Hurlet Coal; but in a few localities where the coal is absent, the divisional line is placed at the base of the limestone or of the Alum Shale beneath it. The entomostracan or white limestone below the coal, included with the Hurlet Seam in the former edition of this memoir, and on the special Glasgow District Map which accompanied it, is now described along with the Calciferous Sandstone sediments, following the practice of the memoirs on the Economic Geology of the Central Coalfield which have been issued since those publications.

On the hand-coloured one-inch maps of the district the upper limit of the Carboniferous Limestone Series was drawn at two different horizons: in the eastern part of Sheet 31 (1875) the Castlecary Limestone was taken as the boundary, but in the west of the same Sheet and in Sheet 30, (1878) where this seam was not identified, the line was drawn at the Calmy (Arden and Robroyston) Limestone, some 50 fathoms lower in the sequence. The higher horizon, the position of which can generally be determined within a few fathoms, is now adopted as the boundary throughout the country, and the colour printed maps of the Glasgow District (1911) and of Sheet 31 (1924) reflect this change. A large area between Milton of Campsie and Garnkirk, and smaller patches within the City boundaries and in the Arden basin, which were coloured as Millstone Grit on the oldest maps, now appear as Carboniferous Limestone.

With the view of exhibiting more obviously the geological structure of the country, two shades were adopted for this Series on the Glasgow District Map, group (3) of the following table being expressed by a paler tint. On the recent edition of Sheet 31, each of the three groups has a separate colour.

The Carboniferous Limestone Series is divided into three groups:—

(3) Upper Limestone Group—from the top of the Castlecary Limestone to the bottom of the Index Limestone.

(2) Limestone Coal Group—from the bottom of the Index to the top of the Top Hosie Limestone—including (ii.) an upper (Possil) subgroup, and (i.) a lower (Garscadden) subgroup.

(1) Lower Limestone Group—from the top of the Top Hosie Limestone[1] to the bottom of the Hurlet Seam.

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[1] Glasgow geologists sometimes include the Johnstone Shell-bed ('Top Marine Band') (pp. 50, 55) in their Lower Limestone Series (Macnair, *Trans. Geol. Soc. Glasg.*, vol. xv., 1915, p. 201; *Proc. Roy. Soc. Edin.*, vol. xxxvii, 1917, pp. 179, 182), but an equally good claim might be made for the marine band in the Black Metals (pp. 57, 64), lying at a still higher horizon amid the coals of the Limestone Coal Group. The upper limit given in the text is more usual and convenient.

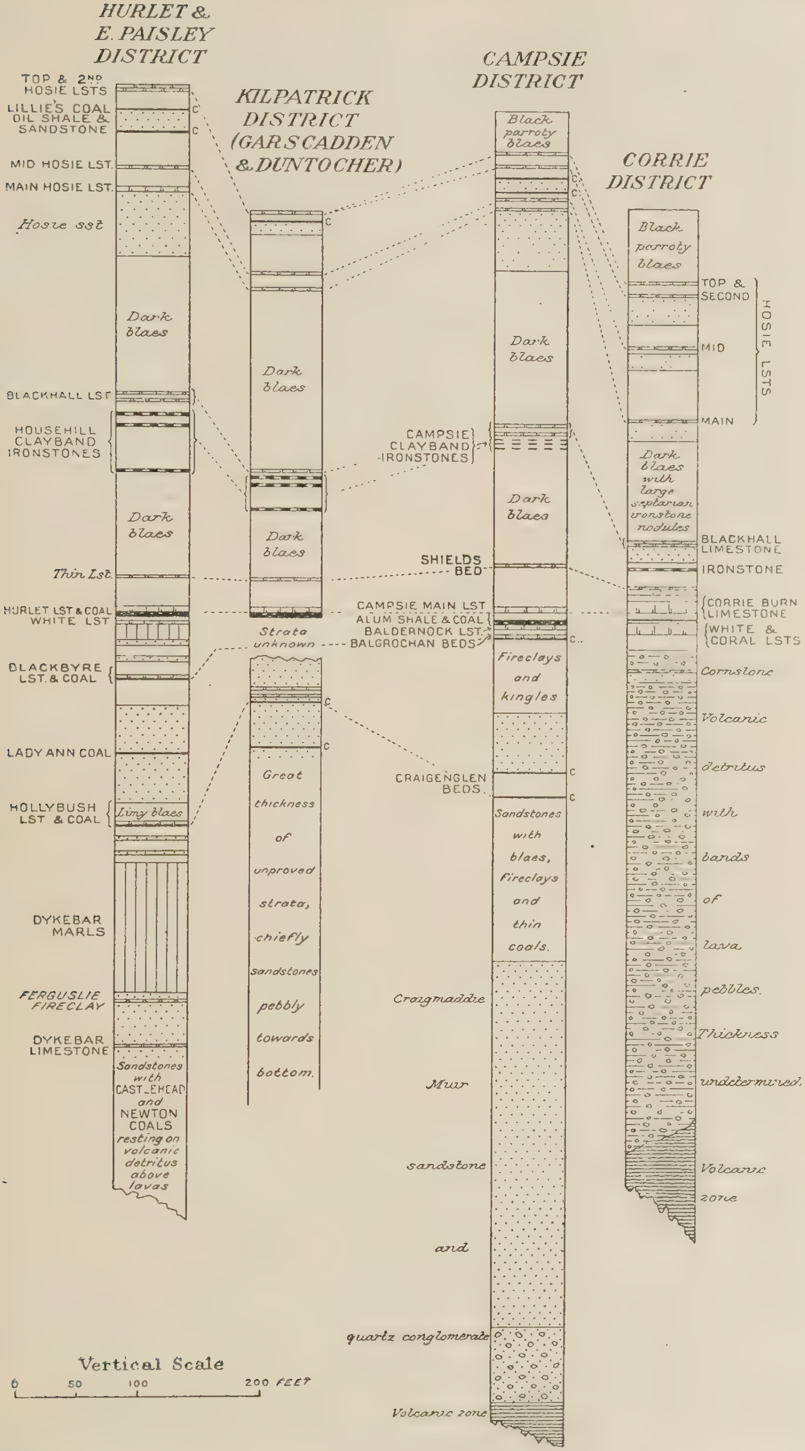

FIG. 2.—Comparative Vertical Sections, Lower Limestone Group, with upper portion of the Calciferous Sandstone Series.

Group (2) was called the Coal and Ironstone Group on the special map and in the previous edition of this memoir; in the mining world it is frequently known as the "Lower Coal Measures."

1. LOWER LIMESTONE GROUP.

In the Glasgow Area this group is composed almost entirely of blaes with thin clayband ironstones, half a dozen beds of limestone, two coals, and only one or two sandstones. It thus presents a strong lithological contrast to the Upper Sedimentary Group of the Calciferous Sandstone Series, in which sandstones, marls and fireclays form the bulk of the sequence (pp. 18, 23).

The work of the Survey and of other observers, especially during the last twenty years, has resulted in a much more definite knowledge of the stratigraphical succession than was before possessed. The sequence set out in the following table is accordingly more detailed than in the previous edition of the memoir, and is one upon which substantial agreement may be said to have been reached among geologists.

The chief horizons now recognized in the group are, in descending order:—

TOP HOSIE LIMESTONE.
SECOND HOSIE LIMESTONE.
LILLIE'S SHALE COAL, in two leaves separated by the LILLIE'S SANDSTONE.
MID HOSIE LIMESTONE.
MAIN HOSIE LIMESTONE, resting on the HOSIE SANDSTONE.
NEILSON SHELL-BED, resting on the
BLACKHALL LIMESTONE.
HOUSEHILL and CAMPSIE CLAYBAND IRONSTONES.
SHIELDS BED (Limestone).
HURLET SEAM (Hurlet or Campsie Main Limestone, Alum Shale and Coal).

Apart from these beds, the group consists entirely of blaes. In particular the presence of only two sandstones is to be noted. West of Paisley even these are absent, but they appear on the western edge of the map and are fairly constant throughout the area, the Lillie's Sandstone, however, being locally absent around Corkerhill and Shieldhall and the Hosie Sandstone near Bearsden. On the North Brae of Campsie and the eastern edge of the map generally, sandstones begin to appear for the first time below the Blackhall Limestone, and in the eastern part of the Central Coalfield are found between nearly all of the chief horizons. C. H .D.

Conditions of sedimentation.—The marked contrast already indicated (p. 15) between the rocks of the Upper Calciferous Sandstone and the Lower Limestone Groups, and the relative difficulty of correlations among the former, show clearly that the Hurlet Seam which forms their boundary marks a change from a local and variable type of sedimentation to one which was both widespread and persistent. The younger group is essentially marine so far as the included fossils are concerned, and the wide distribution of each of the thin beds of limestone shows that at the time of formation of the Hurlet Limestone a great extension of the sea over the land must have taken place.

The thin limestones of the Lower Limestone Group, when comparatively pure, are for the most part made up of encrinital fragments; otherwise they are argillaceous and resemble cementstones, and contain small growth forms of *Bellerophon* and brachiopods. The fine growth forms of the Hurlet Limestone at Corrie and Auchinback are exceptional.

The Blackhall Limestone is remarkable for containing, in its lower portion, ostracods of species usually considered fresh-water in habitat; its oolitic and dolomitic character in the Campsie district is also peculiar. Similar entomostraca are however known from more than one other horizon.

The limestone bands are very subordinate to the great thickness of dark blaes full of organic matter and ironstone nodules. Except immediately above the limestone, these blaes are, save for the occurrence of *Lingula*, generally barren of marine fossils. The finely divided state of the deposits, the quantity of organic matter, the scarcity of marine fossils, the local abundance of entomostraca and the numerous ironstone nodules, all point to the deposition of these strata in or near the sea at the front of the delta of a sluggish river of large volume bringing seaward muds full of organic detritus. Although the sea must have been comparatively shallow, the sedimentation was tranquil, with little scouring by river or marine currents. The limestones mark periods of maximum depression of the land and consequent advance of the sea, coupled with minimum sedimentation over this area; whilst the black blaes were deposited when the increased sedimentation was sufficient to bar such advance. At the close of the period represented by the Lower Limestones the delta deposits of the Limestone Coal Group gradually advanced and covered the whole district. C. B. C.

Variations in thickness.—The thickness of the group is subject to considerable variation over the area, but the change takes place chiefly in the blaes between the beds of the preceding table, and not in general in these beds themselves; the Hurlet Limestone, however, seems liable to considerable increases in thickness, as N. of Lennoxtown, at Corrie, at Auchinback, and to the west and south of Paisley. The following figures indicate the thicknesses of the whole group where known, and minima, with estimated thickness of the whole group, where this has not been proved.

South of the Clyde:—30 fms. at Bridge of Weir; 57 at Greenhead, 2 miles W.N.W. of Renfrew; 74 at Hillington, ½ mile E.N.E. of Rylees, 2 mile S. of Renfrew; 85 at the Victoria Pit, 700 yds. N.E. of Nitshill Station; 100 fms. in the Titwood Bore, Crossmyloof (p. 50). North of the Clyde:—51 fms at Prince Albert Pit, ⅓ mile S.W. of Cleddans, 2 mile W. of Bearsden; 63 near the Roman Catholic College, Bearsden; at least 60 (probably about 75) at Barraston, ⅔ mile S. of Newlands, 1½ mile W.S.W. of Lennoxtown; at least 64 (probably about 80 fms) near Shields, 2 mile E. of Lennoxtown; at least 76, probably over 80 fms., in a bore at Auchinbee, a little beyond the margin of the map, and 1½ miles E. of Strone. At Corrie the group is not much more than 52 fms. thick; and in the Denny district, several miles further east, only 45 fms.

(a) *Hurlet and East Paisley District.*[1]

The *Hurlet Seam* (p. 32) from its economic value and the persistence of the easily recognizable association of thick coal with limestone has long been regarded as a leading datum-line in this part of the country. The limestone itself, varying from 1 to 6 ft. in thickness, is too thin to have been wrought in this district at the surface, but it was taken out along with the coal and alum shale in pits on Hurlet and Househill, where it is stated to have contained 99·8 and 99·5 per cent. respectively of $CaCO_3$.[1] South and west of Paisley, however, the seam approaches 30 ft., inclusive of partings of blaes. It is mainly a dark grey encrinital stone with specks of pyrites. The underlying Alum Shale was formerly wrought for the manufacture of that chemical, and the Hurlet Coal has been more or less exhausted in the southern part of the district, in spite of its content of pyrites, both as nodules and also disseminated through the seam.

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[1] For further details, *see* 'Economic Geology of the Central Coalfield,' Area IV., *Mem. Geol. Surv.*, 1920, pp. 29-39, 48-53; H. M'Phail, 'On the Carboniferous Sections of the Levern Valley, Renfrewshire,' *Trans. Geol. Soc. Glasg.*, vol. iii., part ii., 1869, pp. 254-271; P. Macnair, 'The Hurlet Sequence in North Ayrshire,' *ibid.*, vol. xv., part ii., 1915, pp. 206-210, 217.

Surface exposures of the Hurlet Seam south of the Clyde and east of Paisley are rare. (1) Two feet of the limestone were until recently visible at Hurlet, at an old "ingoing eye" just inside Raes Wood, about 280 yds. S. by W. of West Hurlet House. About a mile to the north-east, a complete section of the seam was exposed in 1905, in the course of building operations for the new Renfrewshire Poorhouses, at Old Crookston. The limestone was found to be 2 or 3 ft. thick, the Alum Shale only one or two inches, and the coal was burnt by a sill of dolerite.[2] (2) In the cutting near Arkleston Junction on the Glasgow and Paisley Joint Railway, the limestone is 3½ ft., the Alum Shale 6 inches thick, and the coal, originally 5 or 6 ft. thick, is divided into two seams by the dolerite intrusion, here 80 ft. in thickness.[3] (3) Fragments of the encrinital limestone may also be observed immediately on top of the sill, which is locally full of burnt coal, at Whinhill Quarry, 700 yds. E. of Blackhall. (4) One mile S.S.E. of Barrhead, in the railway cutting at Auchinback, about 60 yds. S.E. of the bridge, 12 or 13 ft. of limestone are exposed, resting on volcanic detritus above the lavas. The upper part of the seam is split up by shaly partings and crowded with small brachiopods, encrinites, etc.; *Lithostrotion* and cup corals also occur. The overlying strata are cut out by a fault which lets down the Index Limestone.[4] The section closely resembles that of the Main Limestone at Thorntonhall, near East Kilbride, which is now correlated by the Survey with the Hurlet Limestone.[5]

The *Hurlet Coal* has been wrought since the sixteenth century[6] from various pits around Hurlet and Nitshill, to a depth of over 250 fms. It averaged 5½ ft. in thickness, and is mostly taken out between the Crookston and Parkhouse faults (p. 212) on the east and the outcrop to the west. North of the first-mentioned dislocation the coal remains unworked, though probably burnt by the sill already referred to in the direction of Shieldhall and Govan. To the east of this tract and of the Parkhouse fault a large reserve possibly extends from Barrhead and Giffnock to Corkerhill and Crossmyloof: the only bore known to have reached the seam within these limits, put down in the Titwood Colliery, recorded 69 inches of Hurlet Coal at a depth of 213 fms, no mention being made of any igneous intrusion.[7] But before the winning of this reserve is seriously considered, some method of de-sulphurizing the coal, or a process in which the presence of pyrites is a positive advantage, would seem to be required.

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[1] J. Carmichael, 'Account of the Principal Limestone Quarries of Scotland,' *Trans. Highland and Agric. Soc.*, vol. xi. (Second Series vol. v.), 1837, pp. 72, 84.

[2] Area IV., p. 48.

[3] *Ibid.*

[4] Cf. P. Macnair, *Trans. Geol. Soc. Glasg.*, vol. xv., part ii., 1915, p. 217.

[5] 'Economic Geology of the Central Coalfield,' Area VIII., 1917, pp. 15, 33.

[6] 'Statistical Account of Scotland,' vol. vii., 1793, p. 80.

[7] Area IV., *op. cit.*, p. 50, and sketch-map on p. 51.

As in Campsie, a 3 to 6-inch blackband ironstone is found sporadically on the top of the coal in this district.

The *Alum Shale* above the coal varies from 1 inch to 7 ft. in thickness. The alumina, for which it was wrought between 1797 and 1876 or later, is not present in more soluble form in this shale than in other beds of blaes, but is more readily extracted on account of the presence of pyrites and of organic matter. The latter constituent enables a prolonged calcination, lasting 1 to 2 years, to be effected, during which the pyrites is oxidized to ferrous sulphate and free sulphuric acid, which attacks the aluminous silicates of the shale to form an aluminium sulphate. This product is separated from the iron sulphate either before or after the addition of potassium salt required for the formation of alum.[1] Pyritised "orthoceratites" and bivalves have long been known from the old workings of alum shale,[2] but no modern fossil list exists from the shale in this district, the nearest record being at Howwood, 8 miles W. of Hurlet.[3] Only *Lingula* has been found at Arkleston and Blackhall.

The blaes resting on the Hurlet Limestone contains small nodules of clayband ironstone, and the lower 5 ft. yielded a large supply of alum by the "sulphuric acid process."[4] "Alum" blaes was recorded at the same horizon in an old trial shaft 60 yds. W. of the Blackhall Limestone quarry at Tillysow (*see* below); the ironstones were apparently valueless. As at Campsie (p. 41) and elsewhere, these strata are comparatively barren, marine fossils other than *Lingula* being rare or absent—a strong contrast to the beds just above the Blackhall Limestone.

From 3 to 6 fms. above the Hurlet old bores and pit sections often record a thin limestone, 5 to 12 inches thick, which may represent the Shields Bed of the northern districts (pp. 41, 45). This correlation cannot, however, be regarded as established until the marine character of the bed is demonstrated—a matter of some difficulty, since no exposure is known.

The *Househill Claybands* lie in the blaes between this thin limestone and the Blackhall, especially in the upper 8 fms. These are numerous, often slightly calcareous, ironstone bands of which the thickest, reaching 14 inches, were wrought up to quite recent years around Hurlet and Nitshill, and in the Pollok Pit, near Corkerhill.[5] Some of them are exposed in the south bank of the White Cart Water above the sill east of Blackhall, and again in the north bank, ½ mile further east. The associated strata are mostly estuarine, and thin coal streaks have been found among them in bores; petrifactions of *Stigmaria* occur near Bridge of Weir.[6]

The *Blackhall Limestone*[7] is a composite seam—the upper part encrinital, the lower estuarine with fish scales and coprolites and entomostraca—a character which it retains throughout the area. The exposures in this district, which do not show the top of the seam completely, are: (1) at the name locality (old quarry about 200 yds. N.W. of the cross-roads at Tillysow, ⅔ mile E.S.E. of Blackhall steading),[1] where 15 to 24 inches of encrinital limestone rest on 4 ft. or more of entomostracan limestones and blaes; (2) near the old limekiln at Roughmussel Row, 500 yds. N.E. of the cross roads in Hurlet: 18 inches of encrinital overlying 6 ft. of entomostracan beds. The seam[2] was formerly seen in the river close by; (3) in the north bank of the White Cart, south-west of Ross Hall Mains, and 500 yds. E. of Hawkheadmill Bridge. At all three localities some of the blaes partings between the entomostracan limestones are rich enough in organic matter to be termed oil-shales (they are occasionally so recorded in bores); below these a bright yellow-weathering limestone band, followed by a greenish mudstone with irregular irony nodules, are conspicuous features.

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[1] 'Notices . . . Principal Manufactures of the West of Scotland,' *Brit. Assoc. Handbook*, 1876, p. 266; Bryce, 'Geology of Clydesdale and Arran,' 1859, p. 22. Copperas (iron sulphate) was obtained from the shale as early as 1753 (Stat. Account of Scotland, vol. vii., 1793, p. 83.)

[2] Stat. Account of Scotland, vol. vii., 1793, p. 82.

[3] Macnair, *Trans. Geol. Soc. Glasg.*, vol. xv., p. 214.

[4] M'Phail, *op. cit.*, p. 261.

[5] M'Phail, *op. cit.*, p. 262; Area IV., *op. cit.*, pp. 51, 52.

[6] H. R. J. Conacher, *Trans. Geol. Soc. Glasg.*, vol. xvi., 1916, p. 107.

[7] All the six chief limestones from this seam to the Dykebar inclusive have at one time or another been exposed near Blackhall, but the name appears first to have been appropriated to the seam here described by R. Craig (*Trans. Geol. Soc. Glasg.*, vol. v., part ii., 1877, pp. 270-272) who applied it to a 4-ft. limestone, at one time wrought, lying above the dolerite sill near Blackhall, and separated from it by several fathoms of blaes with clayband ironstones up to 6 in. thick (Househill Claybands). On the nomenclature of this seam, *see* also p. 42, footnote 3.

A very fine section of the *Neilson Shell-bed* (p. 42) is exposed near Bridge of Weir,[3] but little or nothing is seen of this highly fossiliferous horizon in the Hurlet district. The more barren blaes and ironstones which succeed it are exposed in the Levern Water, west of Househill, and south of Levernholme, also in the White Cart above Hawkheadmill Bridge. In their upper portion they contain, both here and constantly in the West of Scotland, entomostracan ironstone and limestone bands.[4]

The *Main Hosie Limestone* like its equivalent the Under Limestone of Calderwood[5] rests immediately on the *Hosie Sandstone* wherever that is present (p. 34). The Sandstone is exposed both south and east of Levernholme House and also at Househill. The Main Hosie does not appear here, but is found, a massive encrinital seam, in the river at Barrhead, just below Cross Arthurlie Street bridge, where the strata are near the Househillmuir fault (p. 212), and dip steeply to south-east. It averages 4 ft. in bores, and in Pollok Pit was an encrinital seam in two 2-foot posts, with 3½ ft. of blaes between. The *Mid Hosie*, about 2 ft. thick, is known to be separated from the preceding by two or three fathoms of blaes,[6] but is not now seen; it is believed once to have been visible in the Barrhead section just referred to, and a thin oil-shale still to be seen here may represent the Lillie's Shale.

The *Lillie's Shale Coal*, a few fathoms above the Mid Hosie Limestone, is a seam of considerable stratigraphical importance owing to its wide extent: to the best of our present knowledge its position can be traced continuously at least from N. Ayrshire to W. Fife, and right round the southern edge of the Lanarkshire Coalfield. Except for the possible exposure last referred to, it is not now to be seen in this district, but was found in a well at Househillmuir. To the west of Paisley the shale—a micaceous "parrot" not resembling the true

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[1] This is the 'old quarry at Jenny's Well' (a description more applicable to the old quarry in limestone *beneath* the sill) of John Smith (*Trans. Geol. Soc. Glasg.*, vol. xii., 1902, p. 64), who seems to have been the earliest to observe the entomostracan character of the lower beds, though the associated 'oil-shale' was noted by M'Phail, *op. cit.*, p. 263.

[2] M'Phail, *op. cit.*, p. 262.

[3] Area IV., *op. cit.*, pp. 35, 36.

[4] Area IV., *op. cit.*, p. 36; also Area VIII., p. 32; Area IX., p. 66.

[5] Area VIII., p. 18.

[6] M'Phail, *op. cit.*, pp. 261, 262.

Lothian oil-shales—forms the base of a coal seam, and was wrought as a source of oil, yielding 40 gallons or more per ton. In an old pit, ⅓ mile N.E. of Rylees, the oil-shale was on top of the coal ; while in a bore ⅓ mile E.S.E. of the pit, the seam is described as a coal only—in two leaves divided by the *Lillie's Sandstone* (p. 34), 28 feet thick. In the Victoria Pit, Nitshill, the coal was 30 to 38 inches thick, of which the lower 8 inches were a good cannel, and lay entirely beneath the sandstone, at a depth of 100 fms. The sandstone is wanting in the pit near Rylees, and also in the neighbourhood of the Pollok Pit, Corkerhill, and near Cardonald Station, but this absence appears to be exceptional : it reappears in the Titwood bore between the two leaves of the coal.

The *Top* and *Second Hosie Limestones* are not exposed within the district. From the evidence of bores, and of natural sections west of Paisley, they appear to lie close to each other and may even coalesce into a single bed. The lower seam is a normal encrinital limestone or limy blaes, but the Top Hosie has the dark " calmy " character, invariably associated with it in the west of Scotland, which led to its being wrought as a " cement " limestone at Bridge of Weir, Calderwood near East Kilbride, etc. Specimens of this nature, with the characteristic *Posidonomya corrugata* (p. 46), have been obtained from the Pollok Pit, Corkerhill — the only known record for this district[1]—and strings of small gastropods occur[2] in it, as at Campsie (p. 44).

(b) *Kilpatrick District.*[3]

In this thickly drift-covered region, our knowledge of the sequence is derived almost entirely from bores and shaft-sections ; little or nothing is known of the fossils.

The *Hurlet Coal* has been much wrought north-west of Glasgow. West of Cleddans, near the margin of the map, it is nearly exhausted on the north side of the buried channel of the Kelvin (p. 215) ; further east it has been taken out, between the outcrop and the large downthrow which runs through the Roman Station near Castlehill, as far as Baljaffray, where it was still being mined in 1910. To the east of Baljaffray, as well as in the deeper area south of the fault, the coal remains probably intact, though possibly burnt by intrusive sills towards the R. Clyde. In this district the seam varies from 4 to 6 ft. in thickness, and invariably contains pyrites nodules up to 6 inches in length ; it is separated from the overlying limestone by 6 to 24 in. of Alum Shale, with an indication of the characteristic fauna (p. 40).[4] The *Hurlet Limestone* was wrought along the greater part of its northern outcrop, and was mined formerly along with the coal, which was of a caking nature, near Duntocher,[5] and in recent years at Baljaffray, being of good quality and yielding a " fat " lime. Coal with limestone, probably the Hurlet seam, appear once to have been opened up at Milngavie, between the Mill and Kayston, but were probably in a very disturbed state ; sandstones at a lower, and blaes with clayband ironstone at a higher horizon, may still be seen.

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[1] P. Macnair, ' The Hurlet Sequence in N. Ayrshire,' *Trans. Geol. Soc. Glasg.*, vol. xv., 1915, p. 210.

[2] *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917, p. 182.

[3] *See also* Area IV., *op. cit.*, pp. 77, 78.

[4] ' Catalogue of Western Scottish Fossils,' *Brit. Association Handbook,* 1876, p. 84.

[5] *Trans. Highland and Agric. Soc.*, vol. xi., 1837, p. 447.

The *Blackhall Limestone* lies about 20 fms. above the Hurlet at Prince Albert Pit, 550 yds. S.W. of Cleddans, and is underlain by several ironstones, often recorded as limestones, in the position of the Househill Claybands. Traces of this seam were at one time to be observed on the east side of the rough ground, ¼ mile E. of Snab. A 4-inch limestone exposed in the burn, ⅓ mile W.N.W. of the Roman Catholic College, possibly represents the *Main Hosie Limestone*, though blaes is found beneath it: the Hosie Sandstone is known to be absent in this area (p. 34). The *Lillie's Sandstone*, however, with traces of the coal, is found, and has been quarried just west of Mosshead. The *Top Hosie Limestone*, met with in many bores, is nowhere exposed; it appears to have coalesced with the Second Hosie Seam.

(c) *South and North Braes of Campsie.*[1]

The *Campsie Main Limestone and Coal*, long since recognized as the equivalent of the Hurlet Seam, were wrought at least as early as the end of the seventeenth century. The coal being first extracted, the limestone was then separated from the roof with wedges or gunpowder. The *Main Coal* is a pyritous but caking seam, generally with one or two thin soft ribs. In the South Brae it was from 28 to 54 inches thick, and has been almost entirely removed, so that, the outcrop running right round the hill, the latter is now undermined from side to side. The coal of the North Brae was inferior, and mostly used for burning the lime; it varied from about 4 ft. downward, being only 18 inches in the most easterly record we possess, 300 yds. S. of Shields Cottage. As in the Hurlet district, the top of the coal locally passes into sulphureous blackband ironstone, from 3 to 18 inches thick, which was wrought on the south side of the South Brae, where 10 acres at least have been extracted south-west of Newlands, within the parish of Baldernock. Old workings appear, apparently between two sills of dolerite, at the south side of Craigmaddie Muir; and further south, near North Bardowie, the coal was 2½ to 3 ft. thick; it has also been considerably wrought, with the limestone, near Barraston, ⅔ mile W. of Langshot.

The blaes between the Hurlet Limestone and Coal varies from 2 or 4 ft. in the South to 14 or 15 ft. in the North Brae, where, however, only the lower part was valued as an *Alum Shale*—probably because it was also usually richest in pyrites. Some 12 ft. of the blaes immediately under the limestone are exposed in the Sloughneagh Burn, ¼ mile E. of Bencloich Mains, at the entry of a tributary from N.N.W.; it is very tough and micaceous at the bottom. Still further to the east the thickness again decreases to 8 or 9 ft. near Newmill, Milton, and 3 feet only S. of Shields Cottage. The extraction of iron and aluminium sulphates appears to have been initiated about 1805 in this district.[2]

The fossils in the Alum Shale constitute a marine fauna whose limitations give it a somewhat peculiar character, which is found to extend over a wide area and, when used with caution, affords considerable assistance in correlations of the Hurlet Limestone in districts where, owing to the absence of the thick coal, or for other reasons, this seam cannot at once be identified. A band of ribbed brachiopods occurs close beneath the limestone, and a thin bone-bed of fish remains at the base of the Shale, but the intervening blaes contains little else than the following species of lamellibranchs, the first four or five in especial abundance: *Actinopteria persulcata*, *Streblopteria ornata*, *Myalina verneuili*, *Sanguinolites abdenensis*, *S. costellatus*, *Posidonomya corrugata*. The bone bed is exposed in Glenwynd, S.S.E. of Newlands, and also near Baldernock; the lamellibranch bed has been found at Glorat and Burnel Rannie on the North Brae, and on the South Brae is met with in Baldow Glen and in the workings at Culloch Slap and Boyd's Burn.[1]

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[1] *See* p. 22 for definition of these old topographical terms. The chief references are: 'Statistical Account of Scotland,' vol. xv., 1795, pp. 278, 279, 326-336; 'New Stat. Account,' vol. viii., 1845, Stirlingshire, pp. 170, 239-243, 256, 257; [Dr.] John Young, 'The Geology of the Campsie District,' *Trans. Geol. Soc. Glasg.*, vol. i.: 1st edition, 1860, pp. 24-29, 37, 39-45: 2nd edition, 1868: 3rd edition, 1893, pp. 39-45, 55, 59-72; P. Macnair and H. R. J. Conacher, *Trans. Geol. Soc. Glasg.*, vol. xv., 1914, pp. 44-50 and Plate vi.

[2] 'Notices . . . Principal Manufactures of the West of Scotland,' *op. cit.*, p. 225. *See above*, p. 37, and reference to Bryce there given.

The *Main Limestone* is in general encrinital but otherwise not a richly fossiliferous seam, presenting no outstanding palæontological features (*see* p. 34). It was formerly known here as the "blue limestone" to distinguish it from the "white" seam (p. 24), and was extensively quarried and mined (*e.g.* at Sculliongour). Its thickness averages 4 ft., with extremes of 2 ft. in the west near Bardowie and, by the incoming of flaggy calmy beds on top of the main post, 8 or even 12 ft. to the north of Lennoxtown. (*See* below.) Analysis showed 93 per cent. of $CaCO_3$ and 2·21 of insoluble earthy matter, and the lime was largely used for building and agricultural purposes. Though mostly obscured by old workings, partial exposures may still be observed at a few places:—Barraston Glen, ⅓ mile S.W. of Newlands, where 25 ft. of blaes with small ironstones overlie 3 ft. of limestone; Glenwynd, 500 yds. S. of Newlands; 750 yds. N.E. of Balgrochan, Lennoxtown, where the flaggy limestone above the main 4 to 5 ft. encrinital part contain *Productus*, lamellibranchs, etc.,[2] and the whole section shows an approach to that of the limestone at Corrie (pp. 35, 44); Sloughneagh Burn (3½ ft.); Baught Glen.

An old record of "limy sandstone," forming a good roof to the mines in the western part of the South Brae,[3] probably refers to the thin sill of dolerite or white trap, of which traces may be seen, now above, now below the limestone, in Glenwynd, on the south side of Craigmaddie Muir, ⅔ mile W.N.W. of Newlands, and elsewhere; no true sandstone is known at this horizon.

The blaes between the Main and Blackhall Limestones, 22 fms. thick in the South Brae, contains ironstone nodules throughout. A few marine fossils occur at the base where the Main Limestone is thickening (*see* above), but the greater part of this mass is unproductive, especially in the upper portion.[4] About the middle of the blaes, however, a hard dark granular 2-foot bed of limestone was noted by the original surveyor, the late Dr. R. L. Jack, both in the Baldow Glen and (as a 3-foot almost decalcified encrinital seam) in the Shields Burn just below Shields Cottage. The same limestone has since been discovered elsewhere in the district by Messrs. Macnair and Conacher,[5] (whose convenient name *Shields Bed* will be adopted), and locally contains patches of dolomite. In the Baught Glen, below the cart-track, it is now represented by a black-and-white striped faky sandstone, with encrinites and shell remains.

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[1] P. Macnair, 'The Hurlet Sequence . . . and the Abden Fauna as an Index to the Position of the Hurlet Limestone,' *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917, p. 204; *Trans. Geol. Soc. Glasg.*, vol. xv., pp. 216, 237, 238. *See also* 'Explanation of Sheet 31,' 1879, localities 138, 139, pp. 61, 64.

[2] Macnair and Conacher, *op. cit.*, p. 48, top.

[3] 'New Statistical Account of Scotland,' vol. viii., Stirlingshire, p. 170.

[4] 'Catalogue Western Scottish Fossils,' 1876, p. 71.

[5] *Op. cit.*, p. 47.

In the upper 6 ft. of the barren blaes above the Shields Bed, just below the Blackhall Limestone, lie the *Campsie Clayband Ironstones*, evidently corresponding to the Househill seams of Hurlet (p. 37). They have been wrought to some extent on the top of the South Brae, at Barhill, and near Barraston, and are associated with fish remains,[1] entomostraca, etc. Two thin bands of entomostracan [2] oil-shale, yielding 20 to 30 gallons per ton on test, occur near the ironstones, which are usually in four beds totalling 20 inches thick. In the North Brae they are of inferior quality ; in the Shields Burn they are separated both from the Blackhall, 5 fms. above them, and from the blaes above the Shields Bed, by beds of fakes and sandstone : this appears to be the most westerly appearance of sandstone in this part of the sequence.

The *Blackhall Limestone* [3] retains in Campsie the double character found at Hurlet—encrinital above, entomostracan below. The lower part is dolomitic and often contains ooliths or galls of flint-like material (Shields Burn). The seam has been little worked, but was once wrought opencast on the west side of the Sloughneagh Burn, as well as mined, along with the Campsie Claybands, just south of Barhill steading. Exposures are :—in Baldow Glen ; at upper end of Glenwhapple, ½ mile E. of Newlands ; [4] Sloughneagh Burn, 600 yds. E. by N. of Bencloich Mains ; Baught Glen, just below the Maiden Castle Fort, 350 yds. W. of Garmore (about 4 ft. seen) ; Shields Burn, at two places E. of the Cottage (about 6 ft. thick). Blocks of the limestone also occur in the glen just W. of Muirhead. As in the Hurlet district the limestone is generally in several bands or parts, with shaly partings.[5]

The *Neilson Shell-bed* is the name given to the richly fossiliferous blaes [6] which immediately overlies the Blackhall Limestone. Its main characteristics are not so much the presence of particular fossils as the abundance of species, their generally excellent preservation, and the high proportion of gastropods and cephalopods.[1] The lamellibranch *Posidonomya becheri*, comparatively rare in Scotland, has recently been found among them. The Shell-bed is more or less well exposed[2] in Baldow Glen, Baught Glen,[3] and Shields Burn. In the Sloughneagh Burn, the small Zaphrentid corals which frequently characterize the base of the Shell-bed and the top of the Blackhall Limestone,[4] may be found in some abundance.

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[1] 'Explanation of Sheet 31,' 1879, localities 137 and 141, p. 67.

[2] Full of *Leperditia* (Neilson, *op. infra. cit.*, 1913, p. 335). *Carbonia* also occurs, however, in the ironstones (Young, *op. cit.*, pp. 42, 43).

[3] This seam, the 'coarse black limestone 6 ft. thick " of the New Statistical Account (*loc. cit.*, p. 241), was later named 'Hosie' because of its supposed identity with the Hosie or Foul Limestone of the Carluke district (Young, *op. cit.*, 3rd edn., 1893, p. 42 ; *Geologist*, vol. ii., 1859, p. 468). This correlation is correct, but the name 'Hosie' being commonly used for any of the higher limestones of this Group (*e.g.* below, p. 44, footnote 1, and 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, p. 28) and more particularly for those above the seam in question, confusion has occasionally arisen. The name Blackhall Limestone is accordingly now adopted, the identity of the Blackhall seam (p. 37, footnote 7) with that under description being generally admitted.

[4] Macnair and Conacher, *op. cit.*, p. 47 and Plate v.

[5] Old quarries west and south-west of the mouth of Craigenglen appear to have wrought a limestone, which may have been the Blackhall ; but apart from the doubtful evidence of scattered blocks nothing is known about these workings, or the exact course of the Langshot fault (*see* p. 26, footnote 1).

[6] First described from the old pit on South Brae [⅛ m. N.N.W. of Newlands] by Young (*op. cit.*, 1860, pp. 27, 39 ; *ibid*, 3rd edn., 1893, p. 42 ; *see also* 'Cat. Western Scot. Fossils,' 1876, p. 70) and included, with neighbouring beds, in his 'Hosie Limestone Series.' Mr. James Neilson collected a similar fauna at Thorntonhall, near Busby, and first maintained its importance in correlation with Campsie, Carluke, and elsewhere (*Trans. Geol. Soc. Glasg.*, vol. iv., 1874, pp. 282-290 ; *ibid.*, vol. xiv., 1913, pp. 327-336). While not supported in the first edition of this memoir, these correlations have been confirmed by later work in the west of Scotland and are now adopted in Survey publications (*see ibid.*, vol. xv., 1915, pp. 251, 261, 262 ; 'Economic Geology of the Central Coalfield,' Area VIII., 1917, pp. 14, 33 ; *ibid.*, Area IV., 1920, p. 35).

The blaes above the Neilson Shell-bed contains numerous septarian nodules and bands of clay ironstone, but is poor in marine fossils, and probably becomes fresh-water at the top. It is exposed in the glen west of Muirhead, the burns N. of Glorat House, south of Spouthead, and E.N.E. of Shields Cottage; except at the first-mentioned locality it may be seen to pass up into the *Hosie Sandstone*. On the top of the South Brae this sandstone is the highest horizon known; it was once quarried on a small scale close to Newlands, and is also exposed at Mount Hooly, ½ m. to N.N.W. The same bed was got in a pit to the Campsie Claybands at Castlehill, near Barraston, south of the fault,[5] and was largely quarried at Ferrets on the west side of the Sloughneagh Burn, though much disturbed. It may be seen in most of the burns which descend the North Brae, and in the Shields Burn, due E. of Shields farm, the top foot is full of encrinital debris, as at East Kilbride[6] and at Corrie (p. 45).

The *Main Hosie Limestone* in the Barraston pit shaft was a hard bed, somewhat irony and with cone-in-cone structure in the upper portion. It was a marine limestone, lying near the surface and fully 30 fms. above the Blackhall. A former exposure at the bridge in the burn E. of Shields has been quarried away; the seam was also wrought on the hillside S. of Garmore, and immediately S. of the reservoir, ½ mile E. of Shields, where an adjacent bore shows that the Blackhall lies 38 fms. beneath. The *Mid Hosie*, 20 inches thick, was once seen at the last-mentioned quarry.

The *Lillie's Sandstone* and lower leaf of the *Lillie's Coal* are exposed at the same place, but are better seen in the Shields Burn. Here the lower leaf of the Coal is represented by 6 inches of black parroty blaes; marine ironstones occur below it, and above it some 8 or 9 ft. of fakes and sandstone flags, equivalent to the Lillie's Sandstone, contain a peculiar bed of ironstone nodules in fireclay near their base. The upper leaf of the Coal, resting on the flags, is a micaceous parrot 9 to 12 inches thick, the lowest 3 inches being of good quality and exactly like the seam in the type district at Johnstone, west of Paisley. Five feet higher the *Second Hosie Limestone* is seen—an encrinital seam 6 to 8 inches thick, crowded with small *Chonetes laguessiana* on top, and resting on a thin limy sandstone. Seven feet of fossiliferous blaes come above this seam, and are capped by the *Top Hosie Limestone*—a dark calmy " cement " (p. 39) 12 inches in thickness, with *Bellerophon* [*Euphemus urei*] and other fossils.[1] Some 10 fms. of blaes succeed, in the bottom foot of which *Posidonomya corrugata* is abundant (it has also been recorded from below the Top Hosie here), while *Lingula* and *Euphemus* occur in a band of ironstone about 35 ft. higher ; the rest of the blaes is somewhat parroty, with ironstone nodules and fish scales.

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[1] Mr. Neilson claims however that the majority of the species form a *group* confined to this horizon. A list is given and discussed in *Trans. Geol. Soc. Glasg.*, vol. xiv., 1913, pp. 327-336.

[2] Macnair and Conacher, *op. cit.*, pp. 46, 48.

[3] 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, locality 141, pp. 61, 68, 69.

[4] Carruthers and Richey, *Trans. Geol. Soc. Glasg.*, vol. xv, 1915, p. 251.

[5] Young, *op. cit.*, 1893, pp. 44, 45, 59; the exact site of this pit, in which the Main Coal was 'fully 60 fms. underground' is not known. The Hosie Sandstone here was correctly correlated with that of the Hurlet district by M'Phail, *Trans. Geol. Soc. Glasg.*, vol. iii., 1871, pp. 263, 264.

[6] 'Economic Geology of the Central Coalfield,' Area VIII., 1917, pp. 7, 8, 18.

(d) *Corrie District.*[2]

The first definite correlation of the blue limestone, long wrought in the banks of the Corrie Burn, near Westside,[3] 200 yds. W. of Cairnbog, and on the hill slope to the north, with the *Hurlet* and *Campsie Main Limestone*, appears to be due to Dr. B. N. Peach.[4] Its similarity in colour and texture to the Campsie Main was allowed by Dr. Young, but he never committed himself to their identity.[5] The recognition of the Shields Bed,[6] the Blackhall Limestone, etc., in their proper order above the Corrie Burn seam,[7] together with the finding of the Alum Shale fauna (p. 40) beneath it,[8] seem, however, to render the matter almost beyond doubt, as noted by Dr. Crampton in the first edition of this memoir, p. 25. It may be pointed out further that the nature and thickness of the Campsie Main Limestone N. of Lennoxtown (p. 41), and the eastward thinning of the Coal (p. 40), already indicate a transition from the South Brae to the Corrie Burn character.[9]

The (? Hurlet) Coal below the Corrie Burn Limestone is only 6 inches thick,[10] and is surmounted by thin blackband and nodular clayband ironstone followed by 16 or 17 ft. of papery blaes, with clayband ironstones, *Edmondia*, *Sanguinolites*, and fish remains towards the base, with *Euphemus*, *Posidoniella*, *Lingula*, *Productus*, and Alum Shale fauna[1] higher up, and with abundant *Aviculopecten* at the top. The main post of limestone, 5 ft. thick, which was still being wrought in 1860, succeeds, and is followed by 10 to 15 ft. of limy shales alternating with thin limestones and containing Productids and other brachiopods, encrinites, corals (*Lithostrotion* and *Cyathophyllum*), bands of blaes with well-preserved polyzoa, and others with *Aviculopecten*.[2] Four feet of soft blaes and the same thickness of sandstone and fakes separate these strata from the *Shields Bed*—highly decalcified as in Shields Burn (p. 41) but containing occasional encrinites throughout its 6 ft., with abundant casts of marine mollusca in the lower 15 inches. A few feet higher in the sequence a crimson-weathering granular ironstone perhaps represents the Campsie Claybands. These strata are exposed in the middle burn[3] which descends the dip slope N.W. of the big blaes cliff, and the sandstone which overlies them and is so conspicuous in the neighbouring slopes appears here to be not more than 10 ft. thick.

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[1] The Top and Second Hosie Limestones together constitute the "Bellerophon" or "Hosie" Limestone of the first edition of this memoir, pp. 24, 25, and the "Hosie Limestone" of Macnair and Conacher, *Trans. Geol. Soc. Glasg.*, vol. xiv., 1913, p. 317 ; *ibid.*, vol. xv., 1914, pp. 43, 48.

[2] Chief references :—'Statistical Account of Scotland,' vol. xviii., 1796, pp. 230-234 ; 'New Statistical Account,' vol. viii., 1845, Stirlingshire, pp. 141-144 ; [Dr.] John Young, 'Geology of Campsie,' *op. cit.*, 1st edn., 1860, pp. 29-31, 39-45 : 3rd edn., 1893, pp. 45-49, 59-72 ; Macnair and Conacher, *Trans. Geol. Soc. Glasg.*, vol. xv., 1914, pp. 48-50 and Plate vi. ; Macnair, *Proc. Roy. Soc. Edin.*, vol. xxxvii., 1917, pp. 183-187.

[3] 'Stat. Account,' *op. cit.*, 1796, p. 233, where it is erroneously supposed to be the same as the [Blackhall] seam of *ibid.*, p. 232.

[4] 'Explanation of Sheet 31,' 1879, p. 28, and Sheet 31 geological map, 1875.

[5] *Op. cit.*, 3rd edn., 1893, pp. 46, 47. *See also above*, p. 28.

[6] 'Summary of Progress for 1920,' 1921, p. 49.

[7] The thicknesses of the intervening strata are much less than in the Braes of Campsie, but are parallelled 7 miles to N.E. in the upper Bannock Burn (Summary of Progress for 1919, pp. 36-38).

[8] Macnair and Conacher, *op. cit.*, p. 49 ; Macnair, *op. cit.*, 1917, p. 204.

[9] On the other hand, Mr. D. Ferguson ('The Hurlet Sequence and the Base of the Carboniferous Limestone Series in the Districts of Campsie and Kilsyth,' *Trans. Inst. Min. Eng.*, vol. lii., 1917, pp. 7-32, Plates i.-iii.) maintains : (1) that the Corrie Burn Limestone lies at a much lower horizon than the Hurlet ; (2) that the Hurlet is cut out at Corrie by an unconformity (really, as shown by Plate i., an overlap) affecting strata nearly as high as the Kilsyth Coking Coal—a thickness of over 462 ft. of sediments being overlapped in a distance of as many yards. The question cannot be argued here, but it may be remarked that most geologists who have studied the ground consider that the structures are more naturally accounted for by faulting, and that the invocation of a post-Hurlet overlap, which has never yet been demonstrated east of Ayrshire and Dumfriesshire, is a forced and unnecessary explanation of the Corrie exposures.

[10] *See* p. 29, footnote 2.

The *Blackhall Limestone* rests on this sandstone; its lower dolomitic, oolitic, and entomostracan portion, about 2 ft. thick, has a yellow-brown weathering, angular breccia-like "galls," and some plant impressions, but no marine fossils. The upper portion, in the bed of the burn, is not well seen at present, but is 2 ft. thick, and as usual encrinital, with small Zaphrentid corals (*cf.* p. 43). Young does not appear to have recognized this seam as the Corrie equivalent of his "Hosie" Limestone in Campsie, nor is it clear that he knew of it as distinct from the upper part of the main (Corrie Burn) seam.

Above the Blackhall in the east bank of the middle burn rises the great cliff of blaes noted by all observers. It is some 90 ft. high, with a few feet of sandstone on top, and is studded with layers of septarian ironstone nodules of fair quality, of which the largest, towards the base, used to be collected for Carron Ironworks.[4] Marine fossils occur throughout this mass,[5] but the lowest foot or two is especially rich (Neilson Shell-bed).[6]

The strata between the above and the Second Hosie Limestone are not well exposed, but bore records near Burnhead show the *Main Hosie Limestone* 17 fms. above the Blackhall, and the *Mid Hosie* 10 fms. higher and 6 fms. below the Second Hosie. The Main Hosie may be seen in the eastern burn, a few yards above its junction with the middle burn W. of Cairnbog. It is a yellow-brown weathering seam at least 2 ft. thick, and rests on limy sandstone with casts of marine fossils (Hosie Sandstone, p. 43). Between this point and the bend north of Cairnbog the eastern burn follows the Cairnbog fault, so that sandstones above the Kilsyth Coking Coal occupy the left bank, while one or two exposures of the Top Hosie, dragged down against the fault, occur in the stream.

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[1] According to Macnair, *op. cit.*, 1917, p. 204.

[2] Young, 1st edn., p. 30, *op. cit.*, 3rd edn., p. 48; *Trans. Geol. Soc. Glasg.*, vol. v., 1875, p. 171. *See* 'Explanation of Sheet 31,' localities 159 and 160, pp. 62, 66, 67 (where for 161 read 160).

[3] Usual name for burn next E. from Corrie Burn; the more westerly of the two nameless burns which unite W. of Cairnbog.

[4] 'Statistical Account,' *op. cit.*, 1796, pp. 231-232.

[5] Young, *op. cit.*, 1st edn., 1860, p. 30; 3rd edn., 1893, p. 48.

[6] Cephalopods are especially abundant (*Trans. Geol. Soc. Glasg.*, vol. v., 1875, p. 171) and *Posidonomya becheri* has recently been recorded (*ibid.*, vol. xv., 1914, p. 48).

Higher up this burn, 200 yds. N. of Cairnbog, the *Top Hosie Limestone* is well seen—a dark-grey calmy cement 1 ft. thick; together with the *Second Hosie*—a rough-fractured richly fossiliferous seam of which only the top 6 inches are visible. The 6 ft. of intervening blaes are quite rich in marine shells, including *Sanguinolites costellatus* and *Posidonomya corrugata*; the latter species occurs also near the base of the dark, somewhat parroty blaes (50 ft. or so thick, with layers of *Lingula*) which overlies the Top Hosie. Two further exposures of the Top Hosie occur in the Wham Glen, 200 and 400 yds. S.S.W. of Burnhead.

(e) *Glasgow and Country to the East.*

Little is known about the Lower Limestone Group in this district, where it lies far below the surface, but the Top Hosie Limestone, with a *Posidonomya corrugata* band in the overlying blaes, has been met with in a few recent core-borings. The chief points worthy of note are: (1) the reduction of Lillie's Sandstone to a few feet in thickness; (2) the presence of Second, Mid, and Main Hosie Limestones within 20 fms. of the Top Hosie; (3) the great increase in the distance between the Main Hosie and the Blackhall Limestones, which probably reaches 50 fms.; (4) the appearance in the Group of sandstones other than the Lillie's and Hosie Sandstones — a phenomenon at present known only in the eastern part of the Glasgow Area (p. 34). It may be remarked that in the neighbourhood of Auchinbee, 3 miles S.E. of Corrie, the whole sequence shows a much greater resemblance to that of Robroyston, 7 miles to S.W., than to that of Corrie. C. H. D.

2. Limestone Coal Group.

The Limestone Coal Group of the Glasgow district has, for convenience of description, been divided into two subgroups called, after two well-known mining fields, the Garscadden and Possil Subgroups respectively. The Garscadden Subgroup, extending from the Top Hosie Limestone to the Black Metals, is characterized by a marked development of blaes and clayband ironstones, and contains only one coal of workable thickness. This coal is the well-known Coking Coal of Kilsyth. The Possil Subgroup, on the other hand, ranging from the top of the Black Metals to the Index Limestone, contains a number of valuable coal seams which are locally associated with blackband ironstones. Both subgroups contain ironstones of this nature, but these are more characteristic of the upper one. To the latter belong the blackbands of Pollokshaws and Giffnock, Jordanhill, Possil, Cadder, and Twechar; to the Garscadden Subgroup belong the Upper and Lower Blackband horizons, and the California, Garibaldi and Johnstone Claybands.

The chief horizons are shown in the series of comparative vertical sections given in Fig. 3. M. M.

Conditions of Sedimentation.—The conditions under which the various members of the Limestone Coal Group were deposited are, from the scientific point of view, the most interesting problem which the study of these rocks affords.

Several outstanding features are conspicuous in these coal and ironstone strata. These are: (1) The rapid alternations of beds,

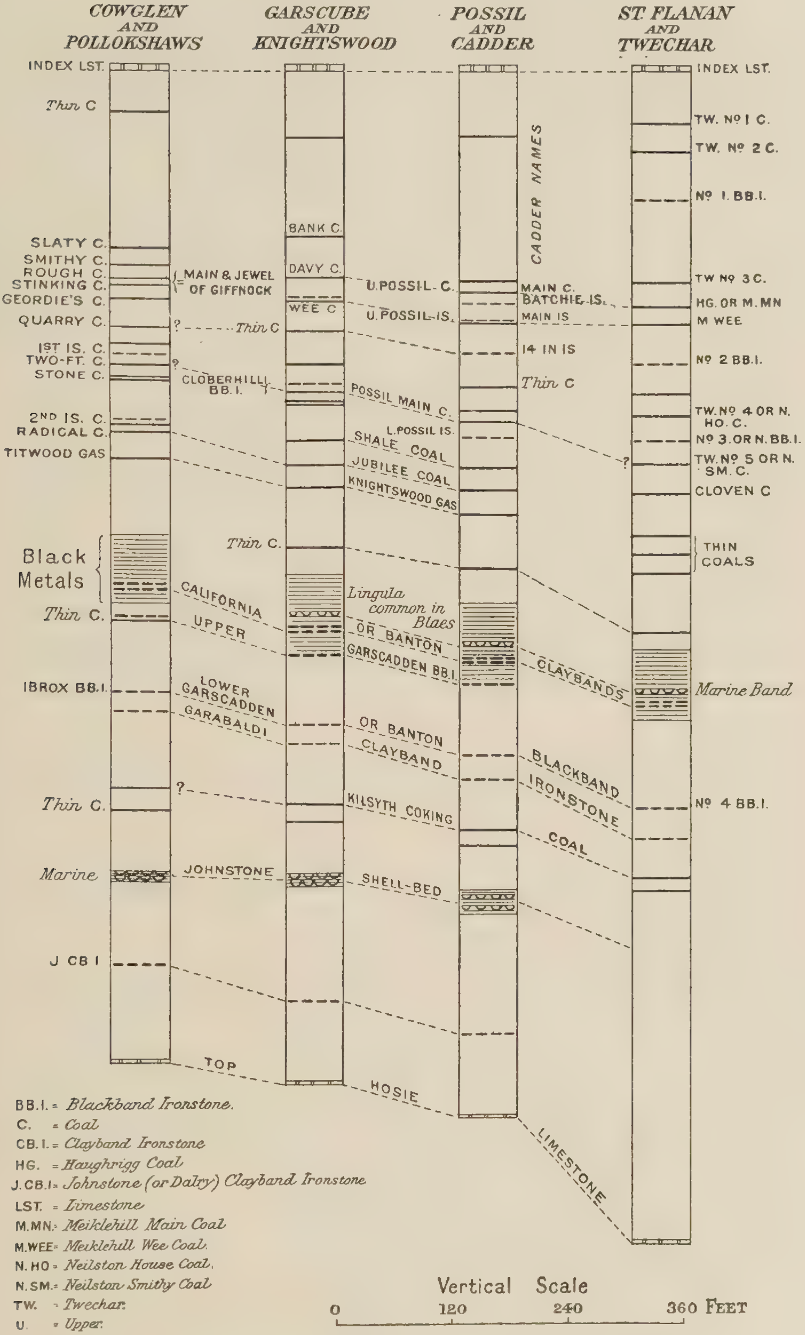

FIG. 3.—Comparative Vertical Sections of the Limestone Coal Group

originally laid down as sand, argillaceous and ferruginous muds, and carbonaceous organic deposits. (2) The very finely divided nature of the deposits, and the long-continued weathering and washing to which the materials had been subjected before being laid down. (3) the great lateral extent of many of the beds and very even surface of deposition. (4) The evidence from organic remains pointing to the growth of plants either immediately upon, or in the close neighbourhood—laterally—of certain beds in the sequence; while other beds, a short distance above or below, may contain marine organisms.

From such evidence, the conclusions may be drawn that these strata must have accumulated over an area where slight subsidence allowed the sea to advance over a wide territory, and where again the water could be driven back by rapid accumulation of sediment so as to permit once more the growth of land or marsh vegetation. Sinking of the wide alluvial flats of a delta deposit meets the first condition, while the concentration of river-borne sediment found at the mouths of large rivers is of equal necessity for the second. The rapid alternation in the nature of the deposits is also accounted for by the great fluctuation in nature of river-borne sediments, and the low angle to the horizon at which the overlap of alluvial and marine deposits takes place. The finely divided nature of the material is due to the coarser fragments being left behind at a great distance inland from the coast, there being nothing of the nature of a beach.

It is probable that extensive stratified deposits of iron compounds can only be laid down at or near sea-level, at those points of a coast-line where large and mature rivers, draining a wide and graded area, debouch into the sea. Only in this way is the iron derived from the rocks of a large extent of country capable of concentration and precipitation over wide areas.

C. B. C.

Variations in Thickness.—The Limestone Coal Group increases in thickness in a north-easterly direction, as is shown by the following figures:—

Paisley and Johnstone district . .	approximately	152 fms.
Pollokshaws and Giffnock . . .	,,	166 ,,
N.W. Glasgow (Garscube, Knightswood, etc.)	,,	172 ,,
N.E. Glasgow (Possil, Cadder, Chryston, etc.)	,,	172 to 186 fms.
Twechar and St. Flanan . . .	,,	200 to 210 ,,

It is known to thin, however, in a south-easterly direction, and in the East Kilbride district, for example, is only 80 fms or so thick..

The detailed stratigraphy will be considered under the following district headings:—

(a) Glasgow District: south of the Clyde.
(b) Glasgow District: north of the Clyde.
(c) Chryston District.
(d) Kirkintilloch and Twechar District.

(a) *Glasgow District: south of the Clyde.*

This district includes all the area south of the Clyde to the east of Renfrew and Barrhead, in which rocks of this group are present either at the surface or concealed beneath higher members of the Carboniferous sequence. Along the axis of the Arden Basin (*see* pp. 202-4) the Limestone Coal Group is overlain in places by more than 100 fms. of Upper Limestone strata, but to the north it comes to the surface and occupies an irregular area of considerable extent. Mining has been carried on in different localities, both for coal and ironstone, but the comparative thinness of the coals has delayed their active development. At the present time (1924) Giffnock Colliery is the only pit in operation.

It is impossible to represent accurately, by means of a single section, the succession in this group over the area as a whole. The upper part of the following table is taken from the record of an old pit at Cowglen, while various borings have been averaged for the portion which underlies the Quarry Coal.

GENERAL SECTION: COWGLEN AND POLLOKSHAWS.

	Thickness.			Depth		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Index or Cowglen Limestone	—	—	—	—	—	—
Strata	30	0	0	30	0	0
Slaty or Sclutty Coal	0	3	4	30	3	4
Strata	2	5	4	33	2	8
Smithy Coal	0	1	6	33	4	2
Strata	1	5	0	35	3	2
Rough Coal	0	2	8	35	5	10
Strata	0	5	5	36	5	3
Stinking Coal	0	1	9	37	1	0
Strata	2	1	8	39	2	8
Geordie's Coal	0	1	4	39	4	0
Strata	4	4	0	44	2	0
Quarry Coal	0	1	0	44	3	0
Strata	4	2	0	48	5	0
First Ironstone Coal	0	1	0	49	0	0
Strata	1	4	6	50	4	6
Two-feet Coal	0	1	6	51	0	0
Strata	2	0	6	53	0	6
Stone Coal { Coal	0	0	10	53	1	4
Blaes	0	0	10	53	2	2
Coal	0	0	10	53	3	0
Strata	7	1	6	60	4	6
Second Ironstone Coal	0	1	6	61	0	0
Strata	1	4	0	62	4	0
Radical Coal	0	2	0	63	0	0
Strata	4	4	0	67	4	0
Titwood Gas Coal	0	2	0	68	0	0
Strata	12	0	0	80	0	0
Black Metals	10 or 12	0	0	92	0	0
Strata	14	0	0	106	0	0
Ibrox or Govan or Lower Garscadden Blackband	0	1	0	106	1	0
Strata	3	0	0	109	1	0
Garibaldi Clayband Ironstones	0	0	10	109	1	10
Strata	13	0	0	122	1	10
Coal (probably Kilsyth Coking Coal	0	0	10	122	2	8
Strata	10	0	0	132	2	8
Johnstone Shell-bed	2	0	0	134	2	8
Strata	17	0	0	151	2	8
Johnstone Clayband Ironstone	0	1	0	151	3	8
Strata	15	0	0	166	3	8
Top Hosie Limestone	—	—	—	—	—	—
Total	166	3	8			

GARSCADDEN SUBGROUP.

The Top Hosie Limestone is overlain by a thick mass of dark blue blaes extending upwards to a few fathoms above the Johnstone Clayband. In a north-easterly direction, however, to judge by the evidence of the deep Titwood boring between Crossmyloof and Maxwell Park Stations, the upper part of these blaes is replaced by sandstones.

Johnstone Clayband.—This clayband is the most persistent of the ironstones in the Limestone Coal Group. It has been worked fairly extensively at various localities—Cardonald, Hillington, Drumoyne, Corkerhill and Nitshill. The sections recorded in the old Hillington workings and at the recently abandoned (1921) Victoria Pits at Nitshill are :—

HILLINGTON.	Ft.	In.	VICTORIA PITS.		Ft.	In.
CLAYBAND	0	10	CLAYBAND		0	8
Blaes	2	6	Blaes	2 ft. 9 in. to	4	6
CLAYBAND	1	0	CLAYBAND		1	0

South and east of these districts very little is known of the development of this seam. It must underlie the whole of the Govan, Ibrox, Pollokshaws, Thornliebank and Giffnock fields. It no doubt thins away eastwards as it does north of the Clyde, and we know it has no economic value in the East Kilbride field. In the deep Titwood bore, near Maxwell Park Station, it showed at a depth of nearly 100 fms. :—

	Ft.	In.
CLAYBAND	0	2
Blaes	2	4
LIMY CLAYBAND	1	3

The following analyses of calcined Johnstone Clayband will illustrate the nature of this seam :—

	Walkinshaw.[1]		Nitshill.[1]	Cardonald.[2]
	1903-1911. Per cent.	Average. Per cent.	Per cent.	Per cent.
Iron (metallic)	40 to 44	42·00	43·76	45·88
Silica	12 to 17	13·95	14·43	12·93
Alumina	7 to 11	9·46	7·60	8·73
Lime	6·5 to 9·0	7·71	5·45	5·82
Manganese	1·0 to 1·6	1·28	1·20	—
Magnesia	2·0 to 4·5	3·26	4·89	—
Phosphorus	·75 to 1·00	0·90	0·87	1·3
Sulphur	·15 to ·30	0·21	0·16	—

Johnstone Shell-bed.—This important marine horizon provides an excellent index-mark for the Johnstone Clayband. It lies 10 to 17 fms. above the latter and 12 or 13 fms. below the equivalent of the Kilsyth Coking Coal. This bed occurs over the whole of the

[1] Communicated by Messrs D. Colville & Sons Ltd., Glengarnock. Walkinshaw lies N.N.W. of Paisley, outside the limits of the Glasgow District Map.

[2] Communicated by Messrs. Jas. Dunlop & Co., Ltd., Clyde Iron Works.

Glasgow district[1] and is readily recognizable in bores from the richness of its fauna. No surface exposures are known in this area and the best section observed in recent years is that in the Pollok Pit, at Corkerhill. In sinking this pit to the Johnstone Clayband, the Shell-bed was found as a dark limy blaes crowded with *Lingula* in the upper part and with an equal profusion of marine forms immediately below; the fossils obtained include :—

Orbiculoidea nitida (*Phill.*)
Productus productus (*Mart.*)
Productus muricatus *Phill*
Schizophoria resupinata (*Martin*)
Rhynchonellid
Myalina verneuili (*M'Coy*)
Sedgwickia gigantea *M'Coy*
Zaphrentis *cf.* enniskilleni *M. Edw.*

Johnstone Shell-bed to Black Metals.—It is not always possible to find a definite equivalent in this area for the well-known *Kilsyth Coking Coal.* Sometimes two coals are recorded near this position, each averaging perhaps 10 to 14 in. in thickness; in the old Freetrader Pit at Nitshill the upper of these is noted in the shaft section as 20 in. thick. At Cardonald a 13-inch coal, lying 32 fms. above the Johnstone Clayband, was worked to a small extent under the name of the Gas Coal, and it is quite possible that this seam is the equivalent of the Kilsyth Coking Coal. It is not known whether the coals mentioned have coking qualities.

Two ribs of ironstone, in the position of the Garibaldi Claybands (*see* p. 56), were formerly wrought to a slight extent at Drumoyne and Ibrox. The section showed—clayband 4 in., blaes 2 ft. 3 in. to 3 ft., clayband 6 in. Three fathoms higher is the Lower Garscadden Blackband, a very variable and inconstant seam, formerly wrought as an ironstone in the Ibrox district under the name of the Ibrox or Govan Blackband,[2] but elsewhere generally replaced by a thin coal. The average section at Ibrox showed—blackband 9 to 14 in., coal 1 to 3 in. There is not much ground in which it is likely to be workable except perhaps round the shafts where it has actually been wrought. The Upper Garscadden Blackband, at the base of the Black Metals, is represented throughout this area as a thin coal overlain locally by one or two ironstone ribs. In contradistinction to the Lower Blackband, which lies in the midst of blaes, this seam invariably rests on a well-marked bed of sandstone. The *Black Metals* are well developed, and show a thickness of 10 to 12 fms. of dark blue blaes containing numerous bands and nodules of clayband ironstone. Occasionally some of these bands reach a thickness of 13 or 15 in., especially near the base of the series (compare the California Ironstones of p. 57). No shelly horizon has been recorded in any of the borings cutting the Black Metals of this area.

POSSIL SUBGROUP.

In past times the Possil Coals were wrought, to a considerable extent, in an elongated area between Barrhead and Pollokshields, where these coals could be won at no great depth. Along this strip of country most of the seams can be traced under various local names ; the small fields that were exploited are more or less contiguous to one another, and may be described as a whole, but correlations of individual coals with those in areas north of the Clyde are, as a rule, difficult to establish. Most of these seams attain their greatest development round Cowglen, but none of them appear to have been of particularly good quality.

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[1] *Cf.* p. 55

[2] Also in the Paisley-Johnstone district under the name of the Lower Blackband.

The lowest seam, known as the *Titwood Gas* or *Splint Coal*, can be identified with certainty with the Knightswood Gas Coal. It does not always contain gas coal, and is hardly a workable seam in the western part of the district considered. It was formerly worked, among other localities, near Govan and Ibrox and more recently from the Lochinch Pit, to the north of Pollok House. Where best developed it contains 6 to 12 in. of gas coal with a layer of ordinary coal above and below, making a total thickness of about 2 ft. Farther south in the deeper part of the basin the seam does not appear to contain any gas coal, but the few bores reaching this position are not very reliable.

From 3 to 6 fms. above the Gas Coal is the *Radical Coal*. This, again, is best developed in the northern part of the area, and may be identified with the Jubilee Coal of the Garscube field. It appears to reach its maximum thickness near the old Titwood Colliery, where it measured 2 ft. 4 in.

Two fathoms or so higher lies the *Pollokshaws Lower* or *Second Ironstone and Coal* which was worked as an ironstone in an old pit just north of the White Cart, and close to Pollokshaws Station. The section of the seam worked is not known but the ironstone was almost certainly a blackband. In the Titwood Colliery it occurred as an ironstone 7 in. thick, resting on a 15-inch coal.

Next in order of succession come two coals which can be recognized throughout the district under consideration. These are the *Stone Coal* and the *Two-feet Coal*. The lower seam, the Stone Coal, was so named because it was frequently divided by a sandstone parting. The seam is thickest in the eastern part of the area, but thins considerably towards the north and also to the south-west, towards Barrhead.

The Two-feet Coal, about 2 fms. above the Stone Coal, is best developed near Cowglen. In this locality the seam is 2 ft. 2 in. in thickness, but further south thins to 1 ft. 8 in.[1] at Nitshill, where it was wrought to a considerable extent under the name of the *Satturland Coal*.

Within the area extending from Nitshill to Titwood and Orchard these two seams are fairly well represented, but nearer the Clyde are too thin to be of economic value, although they are still recognizable in bore sections.

Another coal lies a short distance above the Two-feet seam in the Cowglen section, and was known there as the *First* or *Upper Ironstone Coal*. This seam cannot be identified with certainty round Nitshill, but may be one of two thin coals (one of which contains a 10-inch rib of parrot coal) which lie a few feet above the Satturland seam.

At Cowglen, 5 fms. above the First Ironstone Coal, is the *Quarry* or *Nine-inch Coal*, which was got during the working of the Nitshill Sandstone. This valuable freestone was extensively quarried at Nitshill, where it occurred in two main posts. The upper and thicker bed lay between the Quarry and Satturland Coals ; while the lower bed lay between the Satturland and Stone Coals, and was of such excellent quality that it was got by underground mining. The quarries are now overgrown, but some of the freestone may still be seen under the railway arch.

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[1] 'New Statistical Account of Scotland,' vol. vii., 1845, Renfrewshire, p 153.

A few fathoms above the Quarry Coal is a group of five coals, all close together, and ranging in position from 30 to 40 fms., below the Index Limestone. These are, in ascending order, the *Geordie's Coal*, the *Stinking Coal*, the *Rough Coal*, the *Smithy Coal*, and the *Sclutty* or *Slaty Coal*, the names of the last four seams sufficiently indicating their character. These coals are typically developed near Cowglen (*see* General Section on p. 49), but it is not known how many of the seams were actually worked here. The Stinking Coal was certainly raised and probably some of the others. The "New Statistical Account of Scotland" states[1] that five seams had been wrought at the time of its publication, but this number may include the Gas (or Splint) and possibly other of the lower coals. At the former Lochinch Colliery, 1 mile north-west of Shawlands, six coals were found to occur at about this level. It is probable that the highest of these, which measured only 13 in. in thickness, was an extra seam, and that the next in order, which was 2 ft. 9 in. thick, and was worked to a small extent under the name of the *Cherry Coal*, represents the Sclutty Coal of Cowglen.

Between Lochinch Colliery and the Clyde the condition of these coals has not been adequately proved. Southwards, however, they persist, and the Rough and Stinking Coals are wrought under the name of the *Main* and *Jewel Coals* at the present Giffnock Colliery. The section is :—

		Ft.	In.
Blackband Ironstone	1 in. to	0	6
Blaes		0	5
Main Coal (including two ribs of gas coal)		2	1
Blaes	2 ft. to	4	0
Ironstone Balls		0	6
Parrot Coal		0	6
Jewel Coal	1 ft. 11 in. to	2	3
Sandstone			

Round Nitshill the Geordie's Coal seems to be absent, but two coals occur which may be the Stinking and Rough, while it was probably the Smithy Coal which was wrought as the *Darnley Coal*, and the Sclutty which was worked as the *Boghall Coal* in the old pit of that name. A 3 ft. 6 in. or 4 ft. coal was rather extensively wrought near Barrhead. This was known as the *Barrhead Main Coal*, and it is certainly a member of the same group. R. G. C., E. M. A., M. M.

(b) *Glasgow District : north of the Clyde.*

The area to be now described extends on the north side of the Clyde as far east as Robroyston and Cadder, and includes in addition the Garscadden, Knightswood, Maryhill, Possil, Springburn and Bishopbriggs districts. The general succession in the Limestone Coal Group is shown in the following table, but it must be understood that the figures given here represent approximate thicknesses and average depths and are liable to local variation.

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[1] *Ibid*, p. 36.

GENERAL SECTION OF LIMESTONE COAL GROUP IN NORTH GLASGOW AND CADDER DISTRICT.

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
INDEX LIMESTONE	—	—	—	—	—	—
Strata, chiefly sandstone	11	0	0	11	0	0
COAL, variable and often very thin	0	1	4	11	1	4
Strata, variable; with one or two thin coals	25	0	0	36	1	4
COAL, partly parrot or gas; at Cadder up to	0	2	0	36	3	4
Strata	2	0	0	38	3	4
UPPER POSSIL OR CADDER MAIN COAL, 1½ to 2½ ft.,	0	2	4	38	5	8
Strata	1	3	0	40	2	8
BATCHIE BLACKBAND of Cadder, local and variable	0	1	0	40	3	8
Strata	3	0	0	43	3	8
UPPER POSSIL OR CADDER MAIN IRONSTONE and COAL	0	2	4	44	0	0
Strata	5	0	0	49	0	0
FOURTEEN-INCH BLACKBAND of Cadder, local and variable	0	1	1	49	1	1
Strata, chiefly sandstone, up to 12 fms locally	6	0	0	55	1	1
COAL or coaly blaes	0	1	6	55	2	7
Strata, 3 to 5 fms.	4	0	0	59	2	7
COAL (Blackband at Cloberhill)	0	1	4	59	3	11
Strata	1	3	0	61	0	11
POSSIL MAIN COAL, 2 to 6 ft.	0	2	6	61	3	5
Strata	2	3	0	64	0	5
COAL in two leaves (position of LOWER POSSIL IRONSTONE) say	0	2	0	64	2	5
Strata	5	0	0	69	2	5
SHALE COAL (KNIGHTSWOOD STONE COAL) 1½ ft. to	0	2	6	69	4	11
Strata	4	0	0	73	4	11
JUBILEE COAL (Blackband at Jordanhill)	0	2	0	74	0	11
Strata, 3 to 5 fms.	4	0	0	78	0	11
KNIGHTSWOOD GAS COAL, 1½ ft. to 2 ft. 10 in.	0	2	0	78	2	11
Strata	15	0	0	93	2	11
BLACK METALS (with CALIFORNIA CLAYBANDS and marine bed).	14	0	0	107	2	11
UPPER GARSCADDEN BLACKBAND, local and variable	0	0	9	107	3	8
Strata	12	0	0	119	3	8
LOWER GARSCADDEN BLACKBAND, local and variable	0	0	9	119	4	5
Strata, 3 to 5 fms.	4	0	0	123	4	5
GARIBALDI CLAYBAND, in two ribs	0	1	0	123	5	5
Strata, 7 to 10 fms.	9	0	0	132	5	5
KILSYTH COKING COAL 1 ft. to	0	2	0	133	1	5
Strata	2	3	0	135	4	5
COAL, generally thin about	0	0	10	135	5	3
Strata	7	3	0	143	2	3
JOHNSTONE SHELL-BED, locally as much as	4	0	0	147	2	3
Strata about	20	0	0	167	2	3
JOHNSTONE CLAYBAND, in two ribs, local	0	1	4	167	3	7
Strata about	14	0	0	181	3	7
TOP HOSIE LIMESTONE	—	—	—	—	—	—

GARSCADDEN SUBGROUP.

Five important ironstone horizons are included here—the Johnstone Claybands, Garibaldi Claybands, Lower Blackband, Upper Blackband, and the claybands of the Black Metals. (*See* Fig. 3.) The only coal seam of any economic value is the representative of the Kilsyth Coking Coal.

Johnstone Clayband Ironstone.—This ironstone was worked to a small extent at Garscadden and Knightswood, about the years 1872-86. An average section showed—blaes roof, clayband 6 to 12 in., blaes 2 ft. to 2 ft. 9 in., clayband 7 to 12 in., blaes pavement. It is known from boring evidence to exist in a workable thickness as far east as Maryhill, but in the Springburn and Cadder areas is of no economic value. Westwards the outcrop forms an irregular line running from Yoker northwards by East Kilbowie and Braidfield ; it then meets a N.E.-S.W. upthrow fault, on the north side of which it reappears near South Mains Farm. Just outside the Sheet, in the old Prince Albert Pit near Duntocher, the Johnstone Clayband was found in two 10-inch beds, with 2 ft. 8 in. of blaes between.

Johnstone Shell-bed.—This richly fossiliferous bed has now been shown to have a wide-spread occurrence throughout the Central Coalfield, and to form a very valuable index-horizon. Within the limits of the present area it has been proved in several deep borings at a distance of 9 or 10 fms. below the Kilsyth Coking Coal. It is characteristically in two portions, an upper one with estuarine lamellibranchs (*Naiadites*) and a lower thoroughly marine and very richly fossiliferous bed 2 or 3 fms. thick. The following fossils were obtained from the cores of a boring in the Springburn district :—

From upper part of marine band :—

Lingula mytiloides *J. Sow.*
Lingula squamiformis *Phill.*
Pectiniform shell
Fish scales
? Nucula gibbosa *Flem.*
? Protoschizodus axiniformis (*Portl.*)

From lower part of marine band :—

Encrinite ossicles
Camarotoechia cf. pleurodon (*Phill.*)
Productus sp., fine-ribbed and spinose.
Schizophoria
Sanguinolites cf. omalianus, *de Kon.*
Orthoceras cylindraceum *Flem.*
Edmondia laminata (*Phill.*), var. sublaevis *Hind.*
Aviculopecten

A layer of ? *Naiadites magna* Hind was also obtained a few inches above the marine forms.

The lowest workable coal seam in the series is the *Kilsyth Coking Coal,* which lies at an average distance of 55 fms. above the Top Hosie Limestone and from 120 to 140 fms. below the Index ; its distance from the latter horizon appears to decrease towards the east.

This seam is valuable from its excellent coking qualities and uniform high quality, and can be profitably worked at a considerable depth. For analyses and notes on the coking qualities of this and the other seams beneath the Index, the reader is referred to a paper by Mr. W. Carrick Anderson.[1]

The Kilsyth coal is not at the present time raised in Glasgow or its immediate neighbourhood. There is no doubt, however, that a considerable field of this coal is available at a reasonable depth in an area to the north and north-east of the city which is not yet built over, on the north side of the Comedie fault. Round Bishopbriggs and Robroyston it probably averages 18 to 24 in., but increases in an easterly direction, and at Auchengeich Colliery measures 22 to 36 in. In the western part of the district it appears to be of little or no value ; it is recorded as 12 in. at Balgray, 14 in. at Garscadden, while in the Knightswood-Drumchapel area it perhaps averages 17 in.

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[1] *Proc. Phil. Soc. Glasg.*, vol. xxix., 1898, pp. 72-96 ; quoted by R. W. Dron, 'The Coalfields of Scotland,' 1902, p. 106. *See also infra*, p. 64.

The only locality where any attempt has been made to work it is Knightswood, where it showed—blaes 3 ft., daugh 4 in., coal 17 in., fakes.

The *Garibaldi Claybands* lie a few fms. above the Kilsyth position at the base of a considerable thickness of blaes. They were wrought, up to the year 1892, in the Knightswood, Skaterigg, and Gartnavel fields with an average section of—clayband 4 to 6 in., blaes 2½ to 3½ ft., clayband 6 to 8 in. According to M'Lennan[1] the seam "was so named, in honour of the great Italian hero, by the late Mr. A. M'Luckie, manager at Jordanhill, in 1860." About 1½ fms. below the ironstone occurs a variable and generally thin coal; round Jordanhill this passes into a blackband ironstone, discovered in 1879 in proving a 16-ft. downthrow in No. 8 Pit, and known as the *Jordanhill New Blackband.* This occurrence is purely local however; everywhere else, so far as is known, there is present in this position a coal of 8 to 16 in., which may conveniently be referred to as the Garibaldi Coal.

The *Lower Garscadden Blackband* lies about 3 fms. higher, in the middle of the thick bed of blaes mentioned in the preceding paragraph. It has a much wider distribution than the Upper Blackband. It was formerly wrought in the Garscadden field over no less than eight different areas between which it was apparently too thin to work. An average section[2] showed 5 in. of blackband ironstone on 4 in. of coal, with a blaes roof and floor. Locally it swells to 8, 11 or even 13 in. At Drumchapel it is represented by a 6 to 8-inch coal overlain by 2 to 6 in. of blackband, and much the same section is recorded by borings at Knightswood, Garscube and Maryhill. Farther east again the coal may reach 13 or 14 in., but not until the Kilsyth district is reached does a workable blackband reappear at this horizon. There it is known as Kilsyth No. 4 or Banton Blackband.

The *Upper Garscadden Blackband* lies 10 to 13 fms above the Lower, at the base of the Black Metals. It has been wrought over a considerable area extending roughly from Garscadden south-eastwards to Garscube and Gartnavel. It was last raised about 1894-6 from No. 12 Pit, Knightswood. In thickness it ranged from 4 to 11 in., and sometimes carried a thin rib of parrot at its top. Everywhere else within the limit of the area described it is represented by a thin coal overlain by a 2 to 3-inch clayband rib. The Upper Blackband can always be distinguished in borings or shaft sections from the Lower Blackband by its position at the base of the Black Metals, and by the fact that it invariably rests on a well-marked bed of sandstone.

Black Metals.—The term Black Metals is applied to the thick series of blaes containing ribs and balls of clayband ironstone which occurs in the Central Coalfield about the middle of the Limestone Coal Group. The associated claybands, more particularly in the lower part of the blaes, have been found locally of workable thickness. The following names have been used to designate them in different localities.

North Ayrshire and Renfrewshire—Logan's Bands.
Glasgow District—California Claybands.
Kilsyth, etc.—Banton Claybands.
Wilsontown District—Hogg Fence Ironstones.
Carluke District—Maggie Bands.

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[1] 'Notes on the Jordanhill Coalfield,' *Trans. Geol. Soc. Glasg.*, vol. viii., 1888, p. 274.

[2] Taken from the plan of the old workings.

Most of the claybands in the Black Metals of the Glasgow district vary from 2 to 6 in., but one or two of them show thicknesses of from 9 to 14 in. Those wrought in this part of the Central Coalfield lie 3 or 4 fms. above the base of the Black Metals, and were known as the California Claybands. An average section for the Glasgow district north of the Clyde shows 12 to 15 in. of ironstone in a 3 to 4-foot blaes working. They were wrought at Gartnavel about the middle of last century, and also opened out at a later date in the Garscube field. Eastwards they appear to thicken a little and pass into limy ironstones. The marine band found in the Black Metals over the greater part of the Central Coalfield is not, so far as is known, well developed in the immediate neighbourhood of Glasgow, but it should be added that few opportunities have been offered of examining borings through this position. In the Springburn-Bishopbriggs area the Black Metals have yielded *Lingula* at several horizons, while from near the middle of the series *Orbiculoidea* and Rhynchonellid fragments were obtained. A fairly well-marked marine bed is present over the Garnkirk, Chryston and Bedlay fields, where, in addition to *Orbiculoidea nitida* and Rhynchonellid fragments, *Productus* cf. *productus* has been recorded. In these areas there is very often a 9 to 11-inch rib of impure limestone or limy ironstone in the lower part of the Black Metals corresponding in position to the California Claybands of the ground farther west. *Lingula* again occurs more or less abundantly throughout the upper part of the series, and in one or two borings a band with estuarine lamellibranchs (probably *Naiadites*) was obtained near the top. M. M.

POSSIL SUBGROUP.

The coals of the Possil Subgroup, from the Davy to the Gas seams, have been largely worked in the past throughout the area now occupied by the streets of Kelvinside, Hillhead and Partick. The positions of many of the old pits are still known, and the "wastes" or worked-out coal seams, when near the surface, have at times proved a cause of anxiety to the owners of house property.

The waste of the Gas Coal is known to lie 40 to 50 ft. below the surface on Gilmore Hill. The outcrops of most of these seams were at one time visible along the gorge of the Kelvin between the Belmont Street Bridge and the Kirklee Bridge, but the walling-up and artificial dressing of the banks have now largely obscured the sections. A good section showing the Gas and Jubilee Coals was exposed until recently in the freestone quarries at Eastpark, Gairbraid Street, but these are now filled up. The working face showed the following sequence :—

Dark coaly blaes	
COAL, JUBILEE	2 ft.
Blaes with sandstone ribs	4–6 ft.
Hard sandstone, eroded and thinning towards the west	5 ft.
Faky sandstone	6–9 in.
Grey and dark blaes	6 ft.
COAL, GAS	18 in. to 2 ft.
Fireclay	4 in.
Hard Sandstone	14 ft
Blaes	

The 2-foot coal seen in association with a thick sandstone in the bank above the road leading down to the Maryhill Goods Station is probably a continuation of the crop of the Gas Coal. A fault with a downthrow of 18 fms. to the south-west crosses the Lanarkshire and Dumbartonshire Railway 100 yds. east of the Gairbraid Road Bridge, repeating the strata for some distance beneath the Gas Coal, including a thin coal seam and a considerable thickness of dark blaes with ironstone ribs and nodules. The latter probably belong to the Black Metals. During the construction of the tunnel beneath Tamshill, on the east side of the Canal, an excellent section was laid bare, now of course no longer visible, in which five coal seams, 10 in. to 2 ft. in thickness, together with several ribs of clayband ironstone, were exposed. The stratigraphical position of these metals lies probably between the Gas Coal and the Upper Possil Ironstone, and the coal outcrops presumably include most of the seams of the Possil Group.

Knightswood Gas Coal.—This seam, the lowest of the Possil Coals, lies 70 to 80 fms. below the Index Limestone. It was largely wrought in the Glasgow district at the time when cannel coals were in demand for the manufacture of gas. In the coalfields of Knightswood, Jordanhill, Drumchapel, Blairdardie and Garscube, the average thickness was slightly under 2 ft. (15 to 24 in.), while the rib of gas coal, from which it derived its value, varied from 4 to 10 in. At the old Saracen Colliery at Springburn the seam showed :—

	Ft.	In.
FREE COAL	0	3½
GAS COAL	0	5
FREE COAL	0	9
COAL, streaked	0	7

At Eastpark the thickness was 20 to 24 in., at Hamiltonhill 24 in., while near Bishopbriggs it appears to vary from 22 to 30 in. It is at present wrought at Blackhill Colliery.

The *Jubilee Coal* lies 3 to 5 fms. above the Gas. It was wrought under this name at Garscube where the section showed—coal 16 in., stone 10 in., coal 9 in. In the Jordanhill-Skaterigg field the seam is developed as a blackband ironstone, formerly wrought under the name of the *Old Jordanhill Blackband.* This ironstone was completely worked out between 1837 and 1867, and is said to have averaged 18 in.[1] It persisted as a blackband into the western part of the Balgray-Gartnavel field but was much thinner here and passed rapidly eastwards into a coal. The latter, generally referred to as the Jubilee Coal, averages 20 to 22 in. where best developed.

The next seam above is the well-known *Shale Coal* of Possil. The outcrop of this coal was visible, until recently, in the old quarries on the east side of the road at Lambhill. It was formerly wrought from a mine at this locality, the workings terminating to the south against an east-and-west fault, with a southerly downthrow of about 70 fms.; the coal was also raised from shallow pits between this outcrop and Bishopbriggs, as well as at the old Ashfield, Eastfield and Saracen Collieries on the south side of the large fault referred to. A typical section shows—shaly blaes roof, shale 2 ft. to 2 ft. 6 in., coal 2 ft. to 2 ft. 3 in. The "shale" is of inferior quality, and in most of the deeper borings appear as a dark shaly or parroty blaes locally yielding *Lingula.* It could recently be seen in an old quarry, 200 yds. east of Over Possil, as well as in the Lambhill section already referred to. Farther west, at Knightswood, a coal formerly wrought from Nos. 9 and 12 Pits, under the name of the *Knightswood Stone Coal*, appears to represent the Shale Coal of the Possil district. This seam showed—shale 1 ft. 8 in., coal 15 in., blaes 2 in., coal 15 ins., and lay 8 fms. above the Gas. The *Thirty-inch Coal* of Blackhill Colliery may also be correlated with the Possil Shale Coal.

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[1] *See* M'Lennan, 'Notes on the Jordanhill Coalfield,' *Trans. Geol. Soc. Glasg.*, vol. viii., 1888, p. 273.

A short distance under the Possil Main there is characteristically a seam of coal occurring in two leaves of very variable thickness. From its position in the sequence it appears to correspond to the Cloven Coal of Kilsyth (*see* p. 65), but this correlation is at present only tentative. The seam in question has only been worked within the area under discussion at Hamiltonhill and Saracen Collieries, where a blackband ironstone is associated with it and where it was raised under the name of the *Lower Possil Ironstone.* The section recorded at Hamiltonhill is—parrot coal 3 in., blackband 9 in., dirt 2 in., coal 11 in. Elsewhere this horizon is represented by a coal, generally in two leaves separated by a varying thickness of fireclay.

The *Main Coal of Possil* was raised during last century at most of the pits in the Springburn and Bishopbriggs district. Its thickness varied over this area from 2 to 2½ ft. usually, but fell locally to 18 in. It is at present wrought at Blackhill Colliery under the name of the *Twenty-four-inch Coal.* It was also widely worked farther west at Knightswood, Blairdardie, Drumchapel, Garscube and other localities. The *Knightswood Main* showed a thickness of 25 in., but in the Blairdardie field the seam was considerably thicker. Two sections may be quoted :—

Blairdardie.
(East of Canal).

	Ft.	In.
Fakes and blaes	—	—
Coal	2	4
Parting	0	2
Coal	1	4

Blairdardie.
(West of Canal).

	Ft.	In.
Coal	4	2
Dirt	0	8
Coal	0	10

At Messrs. Dixon's Drumchapel No. 3 Pit, the section was—coal 22 in., sandstone 20 in., coal 12 in., sandstone 15 in., coal 12 in.

Nearly two fathoms above the Main Coal is a small coal passing into a thin blackband at Skaterigg and Cloberhill. It was known at the latter locality as the *Wee Stone* or *Cloberhill Blackband.* Occasionally farther east the coal on this horizon may reach 20 in., but its average thickness is usually 10 to 15 in. There is another and very variable coal two or three fathoms higher which in the old Ashfield Pits at Springburn was known as the "Coking Coal." The strata between the Possil Main and the lowest of the Cadder Ironstones usually measure 10 to 12 fms., but may locally reach 18 fms. They consist, apart from the two coals just mentioned, largely of sandstones corresponding in their position in the Limestone Coal Group sequence with the Nitshill Sandstone of the country south of the Clyde (*see* Fig. 3).

We now come to a group of coals and blackband ironstones which are somewhat more difficult to describe. The lower limit of this group lies about 10 fms. above the Main coal (Knightswood, etc., Main), and the upper limit some 15 fms. higher. It includes the Blairdardie and Drumchapel Blackbands, the Davy and Wee Coals of Garscube, the Upper Possil Coal and Upper Possil Ironstone, the Cadder Main Coal, and the three Cadder Blackbands (the Batchie, Main, and 14-inch). The local development of the blackbands renders exact correlation a matter of some difficulty, and it is a further source of confusion that the same seam has been worked at neighbouring collieries under different names. The following table shows the nomenclature adopted in various parts of the district :—

Springburn and *Hamiltonhill.*	*Gilslochhill.*	*Blackhill.*	*Kenmure.*	*Cadder.*
Upper Possil Coal	Upper Possil Coal	Upper Possil Coal	Upper Possil Coal	Cadder Main Coal
1 fm.	1⅓ fms.	1 fm.	1⅓ fms.	1½ fms.
(Thin Coal)	Upper Blackband	Upper Blackband (Wee Stone)	(Parrot Coal)	Batchie IS.
3 fms.	4 fms.	4½ fms.	3½ fms.	3 fms.
Upper Possil B.B.	Coal with 4-inch clay-band on top	Main (or Middle B.B.	Upper Possil or Main B.B.	Cadder Main IS.
4½ fms.	. .	5 fms.	3½ fms.	5 fms.
(Thin Coal)	. .	Lower Blackband	Understone	14-inch IS.

Cadder Ironstones.—Like all the blackbands of the Glasgow district, the Cadder Ironstones, that fall to be described next, are lenticular impersistent deposits characteristically associated with ribs of gas coal. A very common association is :—

Parrot or gas coal.
Blackband.
Parrot or gas coal.
Free coal.

The ironstone dies away laterally, but the accompanying coal may thicken and persist over wide areas as a workable subject. The accumulation of the materials which now form these blackband ores took place in more or less isolated lagoon-like areas of deposition, the main axes of which appear to have had a N.E.-S.W. trend. A feature of some interest is the recurrence of the same physical conditions in the same districts, so that at one locality we may find blackbands developed at two or three horizons not far apart, while in a closely adjoining district they may be all absent.

These blackbands vary very much from point to point both in thickness and character. Generally speaking they are thin, although very locally thicknesses of 3, 4 or even 7 ft. may be found in " pockets." Often they are only of value from their association with a workable coal.

The Cadder Ironstones are three in number, known from below upwards as the Fourteen-inch, Main and Batchie. The Fourteen-inch Seam occurs over an irregular area extending from Cadder southwestwards towards Blackhill ; the Batchie is developed as a blackband of workable thickness over an area whose limits may be defined by a line joining Cadder, Balmore, Summerston, Caddercuilt, Westfield and Kenmure House. Elsewhere these seams are absent or represented by thin coals with a little parrot locally associated with them. The Main Ironstone corresponds to the Upper Possil Blackband and is really a coal seam of considerable value carrying with it in certain areas a thin rib of blackband ironstone. Eastwards, in the Chryston and Auchengeich fields, it is represented by the Meiklehill Wee Coal (*see* p. 62), while to the west its equivalent is possibly to be looked for in the Wee Coal of the Garscube and Knightswood fields.

The Upper Possil (or Cadder Main) Ironstone was raised over a large area extending eastwards from Maryhill to Robroyston and north-eastwards towards Cadder. An average section shows—clay-band 3 in., blaes 9 to 15 in., blackband 4 or 5 in., coal 18 in.; sometimes a little parrot coal was associated with the blackband. Mining operations in this seam in the Bishopbriggs district ceased about the year 1888, but the ironstone was worked at Cadder No. 17 Pit until quite recently. It occurs as a coal seam of about 28 in. at Gilslochhill, in the Maryhill district, and farther west is in all probability represented by the *Wee Coal* of the Garscube, Gartnavel and Knightswood fields. This coal lies 15 fms. above the Knightswood Main, and in the Blairdardie and Drumchapel fields is partly replaced by a thin blackband ironstone once worked on a small scale under the name of the *Blairdardie* or *Drumchapel Blackband*.

Upper Possil or *Cadder Main Coal*.—This seam lies about 4½ fms. above the Upper Possil Ironstone, the intervening strata including the locally-developed Batchie Ironstone of the Cadder field. It is one of the most important coals in the Limestone Coal Group to the north-east of Glasgow, and corresponds to the Meiklehill Main or Haughrigg Coal of the Kirkintilloch-Kilsyth district. As wrought in the Springburn district it showed two leaves, an upper one about 18 in. thick, and a lower one of 6 to 12 in., separated by 2 or 3 in. of fireclay. Westwards it is probably represented at Garscube by the *Davy Coal*, which lies 3 or 4 fms. above the Wee Coal referred to in the previous paragraph. The Davy Coal is a soft coal, about 2 ft. thick.

The strata between the Upper Possil Coal and the Index Limestone consist chiefly of sandstones and fakes with one or two thin coals and fireclay. On both sides of the River Kelvin, round Garscube and Acre, there is a workable coal, about 7 fathoms above the Davy, known as the *Bank Coal*. It thins out rapidly, however, and becomes unworkable in the country to the south and west. A massive sandstone, 30 to 60 ft. in thickness, usually underlies the Index Limestone, from which it is separated by a few feet of blaes with a thin coal. It is known as the Cowlairs Sandstone,[1] and is well exposed in cuttings on the L.N.E. main line between High Possil Road and East Cowlairs Junction, and on the branch line west of the goods depot at Possilpark. A good example of local erosion is seen at the latter locality, where a thick sandstone rests unconformably upon successive beds of flaggy sandstone and fakes. L. W. H., R. G. C., M. M.

(c) *Chryston District.*

The strata below the Index Limestone nowhere come to the surface in the area between Lenzie and Garnkirk, but the Limestone Coal Group sequence is now well known from borings and shaft sections. It does not differ greatly from that of the Possil-Cadder area, although there are no workable blackband ironstones, and difficulties arise in correlating the individual coals of the lower part of the Possil Subgroup. The valuable seams are the Meiklehill Main, Meiklehill Wee and Kilsyth Coking Coals, and their relative positions are shown in the following table :—

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[1] Correlated with the Dullatur Sandstone in the first edition of this memoir, p. 32. The Dullatur Sandstone overlies the Index Limestone, and corresponds with the Bishopbriggs Sandstone.

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
INDEX LIMESTONE	—	—	—	—	—	—
Strata, 24 to 31 fms.	28	0	0	28	0	0
MEIKLEHILL MAIN COAL	0	2	2	28	2	2
Strata, 2½ to 5 fms.	3	0	0	31	2	2
MEIKLEHILL WEE COAL	0	1	7	31	3	9
Strata	17	0	0	48	3	9
COAL, probably the equivalent of the POSSIL MAIN . . . . . . about	0	1	6	48	5	3
Strata, with several coals	17	0	0	65	5	3
COAL (=KNIGHTSWOOD GAS), say	0	0	10	66	0	1
Strata	16	0	0	82	0	1
BLACK METALS	12	0	0	94	0	1
Strata	25	0	0	119	0	1
KILSYTH COKING COAL, 2 to 3 ft.	0	2	6	119	2	7
Strata . . . . about	53	0	0	172	2	7
TOP HOSIE LIMESTONE	—	—				

The Top Hosie Limestone, associated with dark blaes containing *Posidonomya corrugata* (*see* p. 46), and the Johnstone Shell-bed, 11 or 12 fms. below the Coking Coal, have been reached at one or two localities. The Garibaldi and Banton Ironstones are represented by thin coals overlain by ribs of ironstone at distances of 4 and 9 fms. respectively above the Coking Coal. The marine horizon constantly present in the Black Metals of this area has been already mentioned (p. 57). The group of coals which includes the Possil Main, Shale, Jubilee, and Gas, can be everywhere recognized, although it is sometimes difficult to identify the individual seams. One of them, however, is characteristically overlain by several feet of dark parroty blaes and may confidently be correlated with the Shale Coal of Possil.[1] The Wee Coal, which generally has a thin clayband rib above it, corresponds to the Upper Possil Ironstone of Glasgow, while the Meiklehill Main is on the same horizon as the Upper Possil Coal (*see* Fig. 3). The strata between this seam and the Index Limestone consist chiefly of sandstones varying considerably in thickness, but include thin representatives of the Twechar Coals of Kilsyth (*see* below). L. W. H., M. M.

(d) *Kirkintilloch to Kilsyth.*

Coals and ironstones have been long worked beneath a wide stretch of country in the districts of Kirkintilloch and Kilsyth, and the underground information thus obtained has contributed largely to our knowledge of the succession. The Limestone Coal Group occupies a considerable area between Burnhead and Kilsyth to the north of the Queenzieburn fault, but south of that line it is only within the outcrop of the great dolerite sill in the Kilsyth anticlinal, well known as the "Riggin," that these beds cover any extent of surface.

The following table gives the principal horizons in the Limestone Coal Group of this district, but the thickness of the various seams as well as of the intermediate strata are subject to considerable variation. Westwards and south-westwards from the Twechar area the group is thinner and the workable coals fewer in number (*see* Fig. 3).

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[1] This seam is sometimes referred to locally as the Bannockburn Main.

General Section of Limestone Coal Group, St. Flanan and Twechar.

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Index Limestone	—	—	—	—	—	—
Strata . . . . . 7 fms. to	9	0	0	9	0	0
Twechar No. 1 Coal	0	2	6	9	2	6
Strata . . . . . . about	5	0	0	14	2	6
Twechar No. 2 Coal, 1 to 2 ft. . . .	0	1	6	14	4	0
Strata . . . . . . about	8	0	0	22	4	0
No. 1 or Twechar Blackband, very local .	0	1	1	22	5	1
Strata . . . . . 11 fms. to	14	0	0	36	5	1
Twechar No. 3 or Wee Coal . 1 ft. 4 in. to	0	2	4	37	1	5
Strata . . . . . . about	4	0	0	41	1	5
Haughrigg or Meiklehill Main Coal . .	0	3	6	41	4	11
Strata	3	0	0	44	4	11
Meiklehill Wee Coal . . . 1½ ft. to	0	2	0	45	0	11
Strata . . . . . . about	7	0	0	52	0	11
No. 2 or Haugh Blackband, very local . .	0	1	0	52	1	11
Strata, very variable, average perhaps .	9	0	0	61	1	11
Twechar No. 4 or Neilston House Coal .	0	2	0	61	3	11
Strata . . . . . . about	4	0	0	65	3	11
No. 3 or Neilston Blackband . . .	0	1	0	65	4	11
Strata, 4 to 9 fms.	4	0	0	69	4	11
Twechar No. 5 or Neilston Smithy Coal up to	0	2	9	70	1	8
Strata . . . . . . about	5	0	0	75	1	8
Cloven Coal, in leaves	0	2	6	75	4	2
Strata with several thin coals, 24 to 31 fms. .	27	0	0	102	4	2
Black Metals, 10 to 15 fms.	12	0	0	114	4	2
Strata, 12 to 17 fms.	15	0	0	129	4	2
No. 4 or Banton Blackband	0	0	8	129	4	10
Strata	5	0	0	134	4	10
Garibaldi Clayband	0	0	7	134	5	5
Strata, 5 to 11 fms.	7	0	0	141	5	5
Kilsyth Coking Coal, 2 ft. to 4 ft. 3 in. . .	0	2	6	142	1	11
Strata	2	0	0	144	1	11
Coal (Lower Kilsyth)	0	1	1	144	3	0
Strata, estimated between 45 and 65 fms. .	55	0	0	199	3	0
Top Hosie Limestone						

The Top Hosie Limestone is followed by 8 or 9 fms. of dark blaes well exposed in the burn north of Cairnbog, where they contain layers of *Lingula*. Alternations of sandstones, fakes, and blaes, with one or two very thin coals, continue the sequence up to the Lower Kilsyth seam but little is known of these strata apart from the journals of a few deep borings put down farther east outside the limits of the Glasgow District Sheet. Unfortunately none of these record any fossils in the position of the Johnstone Shell-bed.

The *Kilsyth Coking Coal* crops round a small basin at Cairnbog on the west side of the Braehouse anticline, and was worked here from the Queenzie Pit sunk to it at a depth of 47 fms. On the east side of the anticline it was wrought in shallow pits at Braehead, and in the deeper shafts between this and Kilsyth, at Balmalloch, Allanfauld and Dovecotwood. South of the Queenzieburn fault it has been extensively worked from the present Dumbreck, Auchinreoch, Twechar, St. Flanan, Gartshore, Wester Gartshore, Meiklehill and Woodilee Collieries. It varies in thickness usually from 2 to 3½ ft. Near Kilsyth the roof is of thick sandstone, but over the area further to the south and west it consists of a thin inconstant band of dark sandstone with a ripple-marked surface, varying from 4 to 5 in. in thickness, and supporting a mass of blaes. The latter is often much broken up into small lenticular, strongly slicken-sided portions termed "seeds" by the miners. There appears to have been some horizontal movement along the overlying band of blaes. Where the seeds occur the roof is apt to fall, and has to be carefully watched. The Kilsyth Coking Coal rests on a thin daugh with a sandstone pavement. The uniformly high quality of the coal allows it to be profitably worked at a great depth. Owing to its high calorific standard and small percentage of ash, the large coal is in great demand as a first-quality steam coal, and is chiefly sold as such. From the dross is made the finest quality of coke for foundry purposes. It is locally rather soft for transit for steam purposes, and is then sold as a household coal; otherwise the whole coal is ground down and used, together with the dross, in the production of foundry coke.

The following analyses are quoted from a paper by Professor R. W. Dron, read before the Mining Institute of Scotland, in 1918[1]; those of the Woodilee Main and Cadder Upper Coals being included for comparison.

Colliery and Seam	Percentage of					Caking Index No.
	Moisture	Volatile Organic Matter	Fixed Carbon	Ash	Fixed Carbon in dry ash-free Coal	
Dumbreck: Coking Coal	2·12	37·41	59·09	1·38	61·23	26
Woodilee: Coking Coal	1·06	33·34	64·15	1·45	65·80	22
Auchinreoch: Coking Coal	3·19	35·69	57·06	4·06	61·52	20
Woodilee: Main Coal	3·05	36·42	55·80	4·73	60·51	13
Cadder: Possil Upper Coal	6·88	34·55	52·59	5·98	60·35	10

The Garibaldi Clayband and Banton Blackband Ironstones have been worked on a small scale at Auchinvole as well as at one or two other localities farther east near Kilsyth. They are of very little economic value, however, over most of the area. At Meiklehill, Kirkintilloch and Wester Gartshore the Banton Blackband, for example, is represented by two or three ironstone ribs overlying a thin coal.

The name *Black Metals* has long been used in the Kilsyth field for the thick group of black blaes with clayband ironstones that lies 28 fms. above the Kilsyth Coking Coal, and forms a reliable index to position in boring for coals. All the bores and pits sunk to the Coking Coal between Kilsyth and Glasgow have proved the presence of this horizon, in the same relative position to the coals above and below. The thickest clayband ironstone in these beds is known as No. 9 Clayband Ironstone at Banton and Nethercroy. It sometimes measures 1 ft. 2 in., and generally shows well-marked cone-in-cone structure. The Black Metals are well exposed in the Stoneree Burn half a mile east of Cairnbog, and on the slopes of Barr Hill south of Strone. A band with marine fossils has been noted at the former locality just above the bridge crossing the burn, and is doubtless present in the Black Metals throughout the whole area, although, so far as is known, it has not been recorded in the journals of any of the deep bores. Of the three blackbands in the Possil Subgroup the most persistent is that known as the Kilsyth No. 3 or Neilston Ironstone. It lies 24½ fms. below the Meiklehill Main Coal at Dumbreck and Twechar, and about 21 fms. below the same seam at Solsgirth. At Gartshore it was known as the Upper Ironstone in contradistinction to the Lower or Banton Blackband. It has been worked at a number of collieries and is still raised at Dumbreck. It averages 11 to 14 inches where best developed and is underlain by 1 or 2 ft. of poor oil-shale. or wild parrot coal. An analysis[1] of the stone from Dumbreck Colliery shows :—

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[1] *Trans. Inst. Min. Eng.*, vol. lv., 1918, p. 61, or 'Coalfields of Scotland,' 1921, p. 126.

RAW STONE.	Per cent.	CALCINED STONE.	Per cent.
Iron carbonate	70·00	Iron protoxide	3·60
Iron sulphide	0·65	Iron peroxide	75·20
Manganese oxide	0·60	Manganese oxide	1·20
Calcium carbonate	4·10	Lime	3·80
Magnesium carbonate	0·46	Magnesia	0·70
Clay (silicate of alumina)	8·04	Clay (silicates)	13·00
Phosphoric acid	1·02	Phosphoric acid	1·70
Bituminous matter	14·95	Sulphuric acid	0·90
	99·82		100·10
Metallic iron	34·10	Metallic iron	55·45

No. 2 or Haugh, and No. 1 or Twechar, blackband ironstones are very local in their occurrence ; the former was formerly worked at Haugh Pits, Kilsyth (12 in.) ; the latter at No. 2 Pit, Twechar, about 1883-6 (13 in.). Neither are of any economic value nowadays.

All the coals noted in the general section given above have been wrought at one time or another within the Kilsyth field. They possess to a greater or less degree the quality of caking when undergoing combustion. The Cloven Coal of the Dumbreck and Haugh Pits averages 2½ ft., and derives its name from its being constantly divided by a thin parting into two portions. The *Meiklehill Wee* and the *Meiklehill Main* or *Haughrigg* Coals are extensively worked, the sections at Wester Gartshore and Woodilee Collieries showing :—

WESTER GARTSHORE.	Ft.	In.	WOODILEE.	Ft.	In.
Blaes	—	—	Blaes	—	—
MAIN COAL	2	2	MAIN COAL	2	9
Dirty Coal	0	8	Strata,	9 ft. to 15	0
Sandstone and fakes	8	6			
Blaes	2	6	Blaes	2	8
Clayband	0	2	Clayband balls	0	3
WEE COAL	1	9	WEE COAL	1	7
Sandstone	—	—	Fakes	—	—

At Meiklehill the Wee Coal averages 22 in., the Main Coal 3 ft. ; the latter thickens somewhat in the direction of Kilsyth to about 4 ft. at Twechar and Dumbreck where it is called the Haughrigg.

For the equivalent of these coals in the Cadder and Possil field reference should be made to Fig. 3. The Cloven Coal of Dumbreck is perhaps represented by the double coal a short distance below the Possil Main (horizon of Lower Possil Ironstone). C. B. C., M. M.

The Haughrigg Coal is in the condition of anthracite over a considerable area in the Gartshore district. The anthracite is pure and of good quality, the analysis being as follows :—

Volatile matter	5·10
Free carbon	88·20
Ash	3·90
Water	2·80

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[1] *See* Brand, 'Calcination of Blackband Ironstone at Dumbreck,' *Trans. Inst. Min. Eng.*, vol. xxv., 1903, p. 256.

The dolerite sill in this area overlies the Haughrigg Coal at a distance of 14 to 17 fathoms.

The large coal of the anthracite is exported, while the smaller coal is also often sent long distances, and is in demand for heating grain, etc., its value for this purpose depending on its freedom from cyanides, sulphur, creosote and other volatile products, particularly deleterious in these processes.

These coal workings occur in one of the most disturbed and faulted Carboniferous areas in Scotland. In the country round the "Riggin" the frequently inclined position of the seams, the irregular rolling of the beds, the numerous faults, the presence of the thick dolerite sill overlying the coals, and the depth at which they have to be sought, all cause extra labour and expense in mining. The numerous pits are the outcome of these disturbances, the sinking of additional shafts being in the end less costly than the complicated haulage required where much cross-mining of the faults is necessary.

Except along the centre of the "Riggin," where the whin sill has been removed by denudation, the igneous rock has to be pierced to reach the coals over most of the district. Near Kirkintilloch it sinks to a lower horizon, and the Meiklehill Main and Wee Coals are worked without passing through the sill. All these pits are, however, now sunk to the Kilsyth Coking Coal beneath the whin.

In the Gartshore and Kilsyth areas the intrusion passes above the Main Coal, and the coal is worked as anthracite, where found under the conditions already mentioned, but as a steam and coking coal where it lies at a greater distance from the sill. On approaching the "Riggin" the dolerite again sinks in the metals and burns the coals, rendering them useless, so that in this area the lower seams, the Cloven and the Coking Coals, only can be worked. Between the Gavell-Croy and the St. Flanan faults, however, the whin rises above the Index Limestone, and the Twechar No. 1 Coal, 7 fms. below the limestone, becomes workable over a wide area (*see* p. 154).

The large faults and whin dykes are often of considerable use in forming water-tight compartments in the workings. The dykes, when not in a line of fault, are in some places pierced by level mines, which form a means of communication between the workings in the same seam on either side of the dyke. One of these places in the Barwood Colliery workings has again been made water-tight by "plugging" the mine, a proceeding rendered possible by the resistance offered by the surrounding igneous rock to the pressure on the "plug." This method has saved much pumping operation in keeping the workings dry on one side of the dyke. These level mines through the dykes also afford an opportunity for observing the effect of the intrusion on the coal seam, which is found to shrink to less than half its original thickness, and to be turned into a hard cindery, stone-like mass. At greater distances the coal is sooty and has lost its chief combustible matters, and is described as "burnt." The burning of the coals takes place to a greater distance above than below a whin "float," the distance generally varying directly with the thickness of the intrusion, whether the seam be above or below a sill, or on either side of a dyke.

No satisfactory explanation can be offered of the formation of the anthracite at Gartshore, though there seems little doubt that its origin is connected in some way with the presence of the "whin" sill 14 fms. above it.

Throughout the area where the Haughrigg Coal has been worked in the Gartshore district, the anthracitisation appears to have taken place at a definite distance beneath the dolerite sill. When this distance decreases the coal is burnt, and when it increases the seam becomes a coking coal.

Apart from the presence of the anthracite, there seems some reason for the belief that the sill has offered resistance to the escape of gases from below. It has already been pointed out that the sill passes from a position above the Haughrigg Coal over most of the Kilsyth area to a point below the same seam in the Kirkintilloch district. A comparison of analyses of the Haughrigg Coal from the two areas shows that there is slightly more volatile matter in proportion in the coal where it is workable beneath the intrusion (but not anthracitised), than in those districts where it lies above the intrusion. The Coking Coal, on the other hand, which lies everywhere beneath the whin, contains a constant proportion of volatile matter.

The coking properties of the coals cannot, however, be explained on such a hypothesis, since the coals above the whin, in the Kirkintilloch area, still preserve the coking property. C. B. C.

3. Upper Limestone Group.

The rocks of this group form, on the whole, an arenaceous series, with two well-defined thick sandstone positions and several bands of limestone, most of the latter having a wide distribution, although they are rarely more than a few feet in thickness. The chief limestones are the Index or Cowglen ; the Lyoncross or Holeburn ; the Orchard ; the Calmy, Arden or Garnkirk ; and the Castlecary or Levenseat. In addition to these a thin impure limestone, lying a few fathoms above the Index, is generally present, and from its occurrence in the Huntershill Quarries at Bishopbriggs is known as the Huntershill Cement Limestone. Ten or eleven fathoms below the Calmy a thin band of shelly fakes has been recorded in borings at several localities, while between the Calmy and Castlecary Limestones in the north-eastern part of the Sheet two similar beds, locally passing into impure limestones, are known to occur. The only coals of importance are the Chapelgreen seams, between the Index and Lyoncross Limestones, the Lyoncross Coal a few fathoms under the limestone of the same name, and the Arden, Hirst or Shirva Coals below the Calmy Limestone.

The principal horizons in the Upper Limestone Group are indicated in Fig. 4. M. M.

(a) *Glasgow District : south of the Clyde.*

The Upper Limestone strata below the horizon of the Calmy Seam are characteristically developed in the area south of the Clyde, between Barrhead and Cathcart, where several of the sections about to be described exhibit the typical succession in the lower part of this group. Among the many excellent surface sections available in the country to the south-west of the City, may be mentioned those laid bare in the railway cutting near Nitshill Station ; in Springfield Glen and Waulkmill Glen (where practically the whole of the sequence is displayed) ; and in the large quarries in the Arden Limestone at Darnley. There are also admirable sections in the railway cuttings at Auchinback and on the south side of Barrhead.

The last-mentioned locality lies just outside the map, but is referred to on account of the invaluable evidence it affords of the character of the Index Limestone and the associated sediments.

The *Index Limestone*, a grey "calmy" limestone about 6 ft. thick, usually containing encrinites and shells of *Productus latissimus*, is characteristically overlaid by 10 to 20 ft. of blaes full of small nodules of clayband ironstone but generally unfossiliferous. The crop can be traced more or less continuously round the Arden basin, where it is everywhere succeeded by a massive pebbly sandstone (the *Barrhead Grit*). A well-marked escarpment of this grit runs from Nitshill to Barrhead, and the rock is well seen in the Nitshill railway cutting.

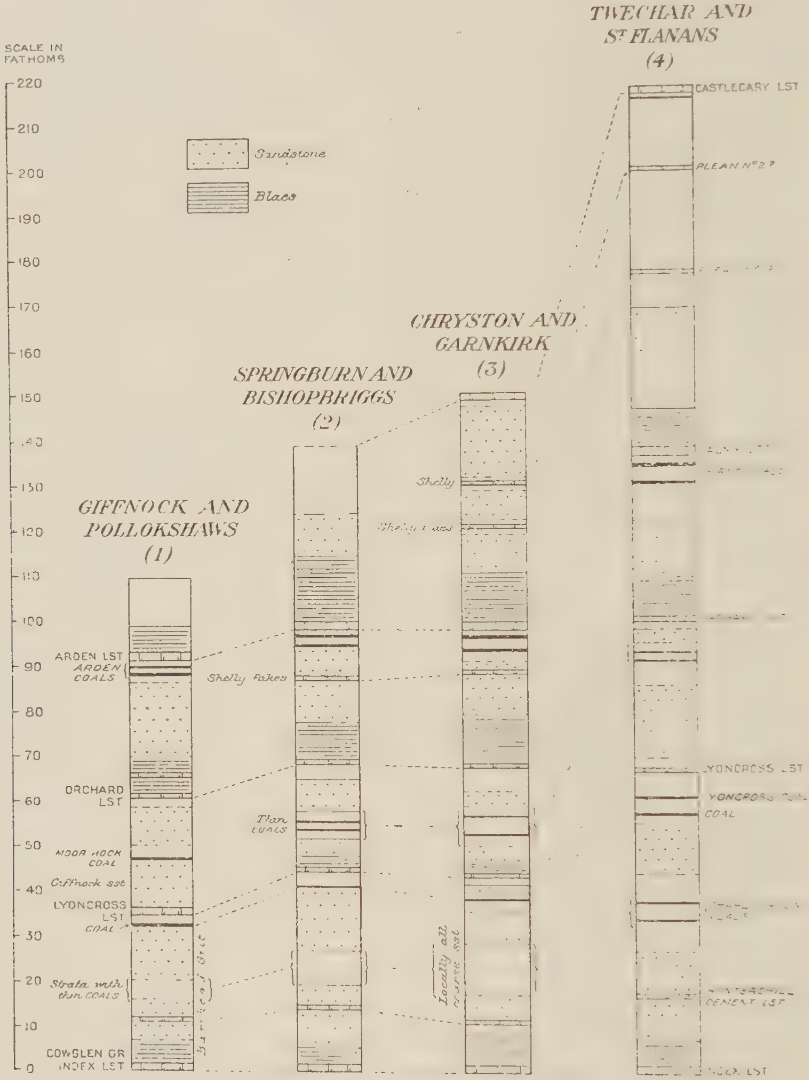

FIG. 4.—Comparative Vertical Sections of the Upper Limestone Group.

The Index Limestone, 10 ft. thick, was found in a pit sunk through the grit escarpment west of Wardhill Farm, but it is not exposed nearer than the south side of the Arden basin, between Barrhead and Busby. Along this southern outcrop the grit rests on the limestone with a slight unconformity, and is often in direct contact with the underlying fine-grained sandstones. This unconformable relation is well seen on the south side of Barrhead in the railway cutting, where there is a notable exposure of the grit, practically continuous with that in Springfield Glen. But the most interesting exposure is perhaps that seen further along the railway at Auchinback. The full section here is :—

Soft pebbly grit (Barrhead Grit).	
Blaes with small clayband nodules	1 ft.
Hard calmy LIMESTONE (Index) ochreous weathering . . .	4 ft.
Fine-grained flaggy sandstones with carbonaceous markings.	

At more than one point in this small section the grit transgresses the limestone and rests directly on the fine-grained flaggy sandstones. The whole section, indeed, closely resembles that seen in the Barrhead cutting further west. The grit and limestone are again seen in a small quarry close by, and also at the east end of the Waulkmill Glen Reservoir, where the limestone, 6 ft. thick, has weathered to an ochreous clay. The stream running northwards through the Glen gives excellent sections of the grit and overlying beds. At the eastern end of the basin the Index Limestone is seen on the left bank of the White Cart, a little below the Overlee Railway Viaduct at Busby, and has been quarried to some extent in the neighbourhood of Cathcart. It was also wrought opencast between Kennishead and Cowglen;[1] from the latter locality it derives one of its names.

The Barrhead Grit near Barrhead extends upwards to the Lyoncross Coal, and has thus a total thickness in this neighbourhood of from 30 to 40 fms.

The *Lyoncross Seam*, 30 to 33 fms. above the Index, consists of a grey, ochreous-weathering, cement limestone, with a coal some 14 ft. below, and is most typically developed south of the river, round the Arden basin. Good sections are exposed in the Nitshill railway cutting, in Springfield Glen, in Waulkmill Glen, etc., where old levels to the coal may be seen. The chief workings to this coal, which is of poor quality and rarely over 2 ft. in thickness, lay to the south and east of Barrhead,[2] but it has been partially worked all round the basin. The limestone itself has been wrought as a cement, chiefly at Waulkmill Glen, where it is covered by several feet of highly fossiliferous blaes, a feature not seen in some other sections. The limestone is usually in two divisions, with a shaly parting, and, as in most Carboniferous limestones, the lower bed is the purer of the two. The Lyoncross Seam is succeeded by about 20 fms. of arenaceous strata, which, round the Arden basin, are separated by two thin coals into three approximately equal divisions. Above these sandstones lies the thick band of blaes containing the *Orchard* cement limestones. These cements are of good quality, and commonly occur in two bands, one at the base and one in the middle of the blaes. The lower bed was worked some years ago near Barrhead, at Little Auchinback, and a trial of it was made in Waulkmill Glen. Both shales and cements have been proved in bores between Kennishead and Darnley, on Dubs Farm, at the printworks in Springfield Glen, and further to the east in the Orchard and Giffnock districts (*see* below).

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[1] 'New Statistical Account of Scotland,' vol. vii., 1845, Renfrewshire, p. 36.

[2] Lyoncross Farm, from which the limestone takes its name, lies a little north of Balgray Reservoir and about 1¼ miles S.E. of Barrhead.

Some 20 fms. above the Orchard shales, and 90 fms. above the base of the group, lies the *Arden* (or *Calmy*) *Limestone and Coal.* As developed south of Glasgow, the limestone is about 10 ft. thick, and, unlike other beds in the Upper Limestone Group, weathers with a light grey colour. It is poor in fossils, but bands in the overlying blaes are often crowded with small organisms. Two coals occur below the Arden Limestone, with the approximate positions and thicknesses shown in the following section[1] :—

	Ft.	In.
Arden or Calmy Limestone	—	—
Strata	5	0
Upper Arden Coal	1	0
Strata, variable	10	0
Lower Arden, North Brae or Auchinback Coal	2	0

The lower seam was wrought on the south side of the basin, near the farm of North Brae, but is very variable and of poor quality. These coals correspond in position with the Hirst or Shirva Coals of the areas north of the Clyde (pp. 73, 78). The limestone is wrought at the present time in the large quarries at Darnley, and there is a good exposure of the well-known *Edmondia punctatella* band in the beds between the limestone and the coal at the mouth of the Darnley fireclay mine.[2] An average section at this locality shows :—

	Ft.	In.
Limestone (worked)	9	0
Limy blaes or impure limestone	4	6
Edmondia slate	0	4
Foul Coal (Upper Arden)	1	0
Blaes	0	6
Fireclay (worked)	2	0
Coal and coaly blaes (probably Lower Arden)	2	0
Fireclay (worked)	4	6

The limestone and associated blaes can also be seen in the Waulkmill Glen, but the coal is there partially obscured. Other outcrops of the seam on the map are inserted from bores, or from the position of old quarries, now filled up. R. G. C.

Giffnock and Rouken Glen.—The first section to be considered in this district is met with in the Giffnock Colliery, near Thornliebank. Here the Index Limestone is about 6 ft. in thickness, and is succeeded by a thick mass of blaes, above which lies a post of sandstone. Next in order, and about 14 fms. above the base of the group, is a thin limestone, which is followed by 20 fms. of strata consisting almost entirely of sandstone. Parts of this sandstone are gritty in character, and the whole zone corresponds to the Barrhead Grit. Above the sandstone is a coal seam to which the name of the Holeburn Coal was formerly applied. It is here 3 ft. in thickness, lies close to the surface, and was formerly worked to a small extent at this locality, but proved to be poor in quality.

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[1] Quoted from 'Economic Geology of the Central Coalfield,' Area IV., *Mem. Geol. Surv.*, 1920, p. 66.

[2] For a detailed account of this section, *see* P. Macnair, 'The Geology of the Rouken Glen and its Neighbourhood,' *Trans. Geol. Soc. Glasg.*, vol. xii., part iii., 1906, pp. 383-385. A section of the *Edmondia* bed exposed during the cutting of a drain on the lands of Davieland near Thornliebank is described by Mr. James Neilson in the same volume, pp. 294-304.

Two fathoms above the coal is the stratum formerly known as the Holeburn Limestone. These two seams are correlated with the coal and limestone of Lyoncross, and will in future be referred to under that designation. The upper seam is a grey cement-like limestone, almost unfossiliferous, and divided into two parts by a band of blaes. It was at one time confused with the Index Limestone, and its recognition as a separate zone is due to the late Jas. Stewart of Williamwood,[1] whose contribution to the geology of this district will be further referred to in Chapter IX. (p. 203).

A very short distance above the last-mentioned horizon is the base of the *Giffnock Sandstone*, and with this the section at Giffnock Colliery closes. The succession for some distance above this point is given by a bore at Orchard, and by the numerous sandstone quarries in the district.

The lower and more valuable portion of the Giffnock Sandstone, termed " Liver Rock " (*see* Chapter XIII., p. 254), is never more than 30 feet thick. Above this lies the " Moor Rock," a coarser sandstone, followed by an impersistent coal,—the " Moor Rock Coal." Sandstone once again succeeds and continues almost up to the position of the Lower Orchard Limestone, which lies about 30 fms. above the Lyoncross seams, and 65 fms. from the base of the group.

The *Lower Orchard Limestone*, a thin band of cement limestone, was at one time wrought at the locality whose name it bears. It underlies a shale, formerly known as one of the best fossiliferous horizons in the west of Scotland, and thoroughly collected in past times by Dr. John Young and other geologists.[2] The sections near Orchard itself are now, unfortunately, almost all obliterated. A second thin band of limestone, to which the name of Upper Orchard Limestone has been given, occurs in the Orchard blaes 5 fms. more or less above the Lower or original Orchard seam. This band was first distinguished by Mr. Stewart. The interval between the blaes and the coal beneath the Arden Limestone is occupied by a series of flaggy sandstones.

The sequence exposed in the Rouken Glen, a deep pre-glacial hollow formed by the Auldhouse Burn in its course through the Rouken Glen Park, a little to the south of Thornliebank, will next be described. Immediately under the bridge which carries the Ardrossan Railway across the stream are some old trial workings for coal. The seam was only a foot thick, and is identified with the Lyoncross. The outcrop of the Lyoncross Limestone, though not seen, must therefore cross the dam a little further to the north. Just below the dam the stream enters the ravine, making a fine waterfall over the hard beds of the Giffnock Sandstone. This sandstone continues along the bottom of the glen very nearly to a point where a band of limestone, about a foot in thickness, is exposed at low water. This is regarded as the Lower Orchard Limestone. The Upper Orchard Limestone forms a more conspicuous feature a little further down the glen. It is in three leaves, and is succeeded by several fathoms of blaes, the base of which, like the limestone bands themselves, is highly fossiliferous. Above the blaes a succession of sandstones, mainly flaggy in character, completes the section exposed in the glen. Further down, the Auldhouse Burn flows through a small reservoir to the north of Deaconsbank, and on the west side of this reservoir the coal underlying the Arden Limestone comes to the surface, but the limestone itself is not now exposed in this neighbourhood.

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[1] 'Notes on the Limestones in the Parishes of Cathcart and Eastwood, Renfrewshire,' *Trans. Geol. Soc. Glasg.*, vol. vii., part i., 1883, p. 158.

[2] J. Armstrong and J. Young, 'Notes on the Fossils of the Orchard Limestone Series,' *Trans. Geol. Soc. Glasg.*, vol. v., 1877, p. 250.

The centre of the basin has now been passed, and the observer, following the burn further north, descends in the sequence, until the horizon of the Orchard Limestones is again reached in the grounds of the Thornliebank Dye, Print and Bleach Works. A rich fauna has been collected from this locality, and described by Prof. Peter Macnair.[1]

Other sections illustrating particular portions of the sequence are discussed in the chapter on the structure of the area (p. 203).[2] E. M. A.

(b) *Glasgow District: north of the Clyde.*

The district now to be described includes all the area north of the river to the south and south-west of Lenzie and Torrance, in which rocks of this group are present either at the surface or concealed by higher members of the Carboniferous sequence.

The *Index* or *Cowglen Limestone*, which forms the base of the group, is a grey, somewhat calmy limestone, usually containing encrinites and shells of *Productus latissimus*, and varies in thickness from 4½ to 6 ft. It is typically overlain by 10 to 30 ft. of dark blaes with balls and nodules of clayband ironstone, succeeded by an important and persistent sandstone horizon. West of Glasgow the Index Limestone averages 5 ft.; its outcrop is known from bores and mining evidence round Drumchapel and Garscube, but only two surface exposures have been noted. The first of these is on the south bank of the river Kelvin, a quarter of a mile south of Garscube House where the limestone is turned up against a large east-and-west fault that runs along the river; the other occurs in the railway cutting on the east side of the aqueduct arch close to Dawsholm Gasworks. R. G. C.

The limestone is again seen, together with the beds immediately above and below it, in the cuttings on the L.N.E. main line between East Cowlairs Junction and Bishopbriggs. These sections are described in detail in a later paragraph (pp. 75-6). The overlying sandstone has been named the *Bishopbriggs Sandstone* from the locality where the stone has been quarried on a large scale.[3] Where best developed the Bishopbriggs Sandstone presents an almost unbroken face of 50 to 70 ft. of massive freestone, but the position is represented in some sections by alternations of thick and thin sandstones with "fakes" or sandy blaes. The sandstone is usually coarse or gritty in texture and often pebbly, especially towards the base, but this is not invariably the case. At Bishopbriggs the pebbles are confined to an inch or two at the base, and the rock is medium or fine in grain; but in the city about Rockvilla and Cowlairs, and south of the Clyde near Barrhead

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[1] 'The Geology of the Rouken Glen and its Neighbourhood,' *Trans. Geol. Soc. Glasg.*, vol. xii., part iii., 1906, pp. 362-397.

[2] The nature and sequence of the strata between the Index and Arden Limestones in this district are treated in fuller detail in a paper communicated to the Glasgow Geological Society by the Officers of the Survey responsible for the revision of this part of the area. *See* R. G. Carruthers and E. M. Anderson, 'The Stratigraphy of the Arden Basin,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part ii., 1908, pp. 133-161.

[3] *See* p. 253. It is also known occasionally as the 'Kenmure Rock.'

(p. 68), the pebbly character is strongly marked. Where exposed by the side of the Kelvin at Dawsholm the upper part of the series is still pebbly, but the lower beds are fine-grained. Between the two lies a thin coal, which can be followed in a line of old "ingoing-eyes" at the base of the grit escarpment, east of the river. A similar division into fine-grained sandstones covered by a pebbly grit is found in the railway cutting north of Temple tunnel.

A thin shelly limestone or cementstone, sometimes in two bands, rests almost immediately upon the Bishopbriggs Sandstone, at an average distance of 10 to 12 fms. above the Index Limestone. This limestone has been recorded in most of the deep borings in the district, and is now known to have a wide distribution throughout the Central Coalfield. From its occurrence at Huntershill Quarries, Bishopbriggs, it is known as the *Huntershill Cement Limestone.* A short distance above it, and nearly midway between the Index and Lyoncross Limestones comes a group of strata containing several thin coals (Fig. 4), corresponding to the Chapelgreen seams formerly worked to some extent near Kilsyth (p. 78). Locally one of these may reach a thickness of 18 in. within the present area. To this group belongs the coal formerly wrought on a small scale at Cadder No. 16 Pit, under the name of the Garnkirk Gas, with the following section:—coaly blaes $2\frac{1}{2}$ in., free coal 1 in., gas coal 7 in. Sometimes the whole interval between the Index Limestone and the *Lyoncross Coal* is occupied by sandstones, coarse-grained for the most part and with pebbly bands. The Lyoncross Coal, 4 or 5 fms. below the limestone of the same name, is only occasionally of workable thickness.

The *Lyoncross Limestone* varies in thickness from a few inches to over 2 ft., and frequently occurs in two bands. It is overlain by several feet of shelly blaes, succeeded by a sandstone in the position of the well-known freestone of Giffnock (p. 71). The *Orchard Limestone,* 22 to 24 fms. above the Lyoncross, and 1 to 3 ft. in thickness, is generally easily recognizable in borings by the overlying Orchard blaes, a series of dark mudstones, sometimes 20 fms. thick, containing numerous clayband ironstone nodules. The lower 2 or 3 fms. of these blaes are fossiliferous, and a few feet above the limestone there is very often a thinner highly calcareous band in the position of the Upper Orchard Limestone of the area south of the Clyde (p. 69). The strata above the Orchard blaes, up to the horizon of the Hirst Coals, consist chiefly of sandstones and fakes, but include a thin band of impure shelly limestone lying 10 or 11 fms. below the Calmy. The *Hirst Coals* are two in number :—

CALMY LIMESTONE.
Strata, 6 to 8 ft.
UPPER HIRST COAL.
Strata, 2 to 3 fms.
LOWER HIRST COAL.

The lower seam is rarely of workable thickness but the upper one has been wrought in the Robroyston and Cadder fields. At No. 16 Pit, Cadder, the working section showed—coaly blaes 4 ft. 4 in., fake rib 3 in., free coal 3 ft., faky fireclay. Both seams appear to deteriorate eastwards towards Garnkirk and Chryston. A few feet of dark, often calcareous blaes, which includes the *Edmondia punctatella* slate (*see* below), separates the Upper Hirst Coal from the *Calmy*

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[1] Also at Balquharrage, 1 mile N.W. of Kirkintilloch. *See* Young, *Trans. Geol. Soc. Glasg.*, vol. i., part i., 1860, pp. 31, 38.

Limestone. This limestone is known by many names—the Arden, the Hirst, the Robroyston, the Garnkirk, and other local designations. It occurs typically in two leaves separated by a few inches of limy blaes and may reach a total thickness of 10 ft. An average section shows—limy blaes, limestone 2 ft. 8 in., limy fakes or blaes 9 in., limestone 3 ft. 4 in., limy fakes or blaes 1½ ft., brownish parroty blaes, 7 in., fireclay. The limestone is hard, fine-grained and compact, bluish or dark grey in colour, often with ochreous weathering, and breaks with a conchoidal fracture. The parroty blaes ("*Edmondia* slate") below it is an exceedingly valuable horizon for identifying the Calmy in borings; it contains the lamellibranch *Edmondia punctatella* (Jones), a fossil characteristic of this position in other parts of the Central Coalfield, as well as in Ayrshire, Renfrewshire and West Fife.

The Calmy Limestone is nowhere well exposed in the immediate neighbourhood of Glasgow, but is still visible in the old quarries at Robroyston.[1] Both the limestone and the coal were at one time laid bare in the Caledonian (now L.M.S.) Railway cutting near Provanmill, half a mile north-west of the west end of Hogganfield Loch, and the North British main line to Edinburgh (L.N.E. Railway), nearly 1 mile east of Bishopbriggs Station, but the sections are now largely obscured. At the former locality 3 ft. of limestone can still be seen. Farther east the Calmy is exposed, sharply folded with the Hirst Coal, in the small stream near South Loch on the south side of the Claddens-Auchinloch dyke, 1 mile S.W. of Lenzie. It has been worked from several shallow pits between Garnkirk and Muirhead on the north or upthrow side of the Garnkirk fault. The isolated outcrop of this seam around a flat dome at Chryston (Fig. 17) affords some interesting sections. The limestone, together with the coal below, is exposed on the Gargaber mineral railway, close to the Glasgow Road bridge, and is in conjunction with, and slightly indurated by, the Bedlay dolerite dyke, where the latter is quarried beneath Bedlay Cemetery. The Chryston outcrop is cut off to the north by a large fault running in an approximately east-and-west direction through Moodiesburn, and probably continuous with the fault described on p. 87, as passing through Leckethill Cottages and Bridgend just east of the margin of the Glasgow District Map.[2]

The Calmy Limestone is succeeded by a considerable thickness of blaes with ironstone nodules, followed usually by a thick sandstone, which is quarried for moulding sand near Avenuehead, east of Chryston.[3] We have little information as to the remainder of the sequence up to the Castlecary Limestone within the limits of the map, but it appears to be largely made up of a succession of fakes, blaes and sandstones. At two horizons (Fig. 4) shelly fakes and blaes have been met with corresponding to two of the limestones known in the Plean area as the Plean Limestones.[4]

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[1] *See* J. Young and J. Armstrong, 'The Fossils of the Carboniferous Strata of the West of Scotland, No. 1. Robroyston,' *Trans. Geol. Soc. Glasg.*, vol. iv., 1874, p. 267.

[2] A conjectural continuation of this fault is indicated on the Glasgow District Map as running north-west towards Gartferry House, but it seems clear, from recent mining information, that it takes the more westerly direction through Moodiesburn.

[3] *See* p. 255.

[4] 'Economic Geology of the Central Coalfield,' Area II., *Mem. Geol. Surv.*, 1917, pp. 21-22.

The *Castlecary* or *Levenseat Limestone*, so called from the localities where it is best developed and has been extensively worked, is now adopted throughout the country as the top of the Carboniferous Limestone, whereas, on the original maps of the Survey, the divisional line between that formation and the Millstone Grit in the Glasgow district was drawn above the Calmy Limestone.

The Castlecary band is nowhere exposed within the limits of the Glasgow Sheet, and little is known about it. It has been proved in two or three borings in the Garnkirk-Glenboig district, at a distance of about 50 to 53 fms. above the Calmy Limestone, and a few fathoms below the Roman Cement Limestone (pp. 82-3). A recent boring put down a little south of Cardowan House showed a 19-inch, light-grey, argillaceous limestone 50 fms. above the Calmy and 4 fms. under a thin shelly band taken to represent the Roman Cement. An old boring at Garnkirk Fireclay Works records the following section 53 fms. above the Calmy—limestone 14 in., blaes 1 in., limestone 20 in.; but in such cases it is very difficult to decide whether we are dealing with the Castlecary or with one of the marine horizons in the lower part of the Millstone Grit Series. The Castlecary is perhaps represented at Saughs, a little west of Steps Road Station, by a hard grey limestone in two bands, 4 ft. 11 in. and 2 ft., with a 1-inch parting, proved at a depth of 19 fms.

In the neighbourhood of the city itself nothing definite is known of this horizon. There is a record of a 33-inch limestone at a depth of 6 fms. in an old boring, 400 yds. west of Garngad Road Station, which may be the Castlecary, while it is reported to have been reached in two borings at Glasgow Green. One of these shows :—

LIMESTONE, 16 in. at 112 fms.
LIMESTONE, 7 in.
Blaes, 22 in.
LIMESTONE, 8 in. at 142 fms. 1 ft. 4 in.
Foul COAL, 14 in. at 143 fms. 5 ft. 2 in.

This boring appears to have commenced in the lower part of the Coal Measures under 13 fms. of "sand and mud." Possibly the upper limestone represents the Castlecary and the lower one the Calmy. The Castlecary is again possibly represented by the $9\frac{1}{2}$-foot limestone cut at a depth of 52 fms. in a bore put down in 1903 at Messrs. Paterson and Sons' Works in Charlotte Street, and if so its thickness may be due to the high inclination of the beds against a fault passed through immediately below the limestone.[1] The deep boring at Wellpark Brewery records a 5-foot limestone at 117 fathoms, but here again, owing to the position of the bore, the evidence is unsatisfactory.

In a boring on Balmore Haughs, nearly half a mile south-east of Bardowie Loch, a limestone, 2 ft. 4 in. thick, was met with $53\frac{1}{3}$ fms. above the Calmy position, and is taken to represent the Castlecary. It lies at a depth of 64 fms.—41 fms. of the distance being occupied by surface deposits. L. W. H. ; M. M.

Sections at Bishopbriggs.—Good sections of the strata immediately above and below the Index Limestone are exposed in the cuttings on the main line of the North British (now L.N.E.) Railway between Cowlairs East Junction and Bishopbriggs.

The massive false-bedded sandstone seen in the cutting on either side of the bridge that carries the cart-track to Colston across the railway, represents the Cowlairs Sandstone—beneath the Index. Immediately south of this bridge the former has intercalated with it some blaes bands and a thin coal, which is cut off further to the south by a small cross fault. The sandstone dips gently to N.N.E., and the higher beds that come on at the bridge on the High Possil Road are thin-bedded and faky. These are followed, 40 yds. or so north of the bridge, by dark blaes and a thin coal, which immediately underlies the Index Limestone. The outcrop of this limestone can be followed for some distance along both sides of the cutting until it dips at a gentle angle beneath the rails. It is a hard, grey, ferruginous dolomite, averaging 4 ft. in thickness, with a rough concretionary and ochreous weathering, and contains a few fossils, including *Productus latissimus*, determined by Mr. John Young. The limestone is succeeded by a varying thickness of dark blaes containing flattened ironstone nodules, and, in the upper part, large concretionary masses of ferruginous sandstone. The upper surface of the blaes band shows evidence of considerable erosion prior to the deposition of the overlying sandstone. The unconformable relations of the blaes and sandstone are seen on the east side of the cutting, where the latter transgresses the higher beds of the blaes containing the sandstone concretions, and approaches nearer and nearer to the position of the limestone. The base of the sandstone is pebbly, and largely made up of fragments of ironstone nodules from the blaes below.

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[1] *See* p. 81.

Evidence of local unconformity is also to be seen in the old quarries on the west side of the line, though the best examples are now obscured. At one place in the South Coltpark Quarry, thin flaggy sandstones, inclined to the north at 60°-65° appear to be overlaid by thick-bedded strata resting at a gentle angle, with a slightly different direction of dip.[1] The vertical sides of the cutting beyond the limestone outcrop are formed of the massive Bishopbriggs Sandstone. A small fault running E.N.E. traverses the sandstone close to the Coltpark Avenue Bridge. A hundred yards beyond this bridge, a band of shelly limestone, intercalated in the sandstone, gives rise to a conspicuous feature along the walls of the cutting. It is 1 ft. in thickness, dark grey in colour, with bright ochreous weathering, and full of fragments of marine fossils. This bed seems to be entirely local in its occurrence.

The Bishopbriggs Sandstone is at the present time best exposed in the quarries and mines at Huntershill. The working face shows 60 to 70 ft. of sandstone, and the underlying dark blaes and Index Limestone have been proved in the bottom of the mine. A fuller description of this sandstone will be found on p. 253.

The cementstone which overlies the sandstone is exposed along the face of the Huntershill quarries and also in the old Crowhill quarry, but is in most places inaccessible. Though locally known as "the cementstone," it has little or no economic value as a cement, and is rather a hard, grey, impure limestone, which, together with the overlying calcareous blaes, is in places highly fossiliferous.[2]

The disused Crowhill quarries afford sections of the strata for a short distance above the cementstone, including grey blaes with limestone nodules, followed by alternations of blaes, fakes, and thin-bedded sandstones with shaly partings, and one or two thin coals.

The accompanying vertical section (Fig. 5) represents the strata from the Cowlairs Sandstone up to a point about 125 ft. above the Index Limestone, as displayed in the sections described above.

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[1] *See also* paper by Prof. John Young and Mr. John Young, on 'Local Unconformity,' *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, p. 283.

[2] For lists of fossils obtained from this horizon and from the Index Limestone, *see also* the paper by Messrs. Young, quoted above, pp. 289-290.

The next rock cutting, at Myremailing, ½ to a little over ⅔ of a mile east of Bishopbriggs Station, affords a section of strata at a considerably higher horizon than those last described, and has already been referred to (p. 74). From the bridge at South Crosshill the railway passes through sandstones—pierced by a dolerite dyke along which the sedimentary rock is slightly indurated—followed by dark blaes with ironstone ribs and nodules, and alternations of blaes and faky beds, the strata dipping north-east at 10°-12°. At a point 500 yds. east of the bridge, a bed of hard, somewhat crystalline limestone, 2 ft. 3 in. in thickness, occurs in the blaes. The outcrops of the Calmy Limestone and Hirst Coal cross the line 250 yds. further east, but their exact position is now concealed. The position of the above-mentioned limestone is calculated to be about 25 fms. below the Calmy, and it is thus possible that it represents the Orchard Limestone, though not in its characteristic aspect. L. W. H.

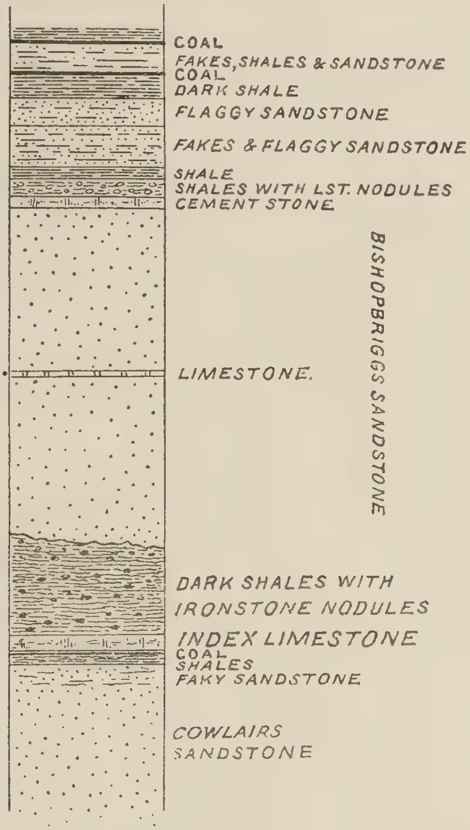

FIG. 5.—Vertical section of strata at Bishopbriggs.

(c) *Kirkintilloch to Kilsyth.*

The rocks of the Upper Limestone Group occupy nearly the whole of the area between the fault that runs eastwards from Milngavie through Milton to Kilsyth, and the Kelvin and Luggie Water. Over the greater part of this area the country is thickly covered with superficial deposits, natural sections are few and limited in extent, and our knowledge of the sequence and character of the strata is chiefly derived from the numerous pits and bores put down to the coals beneath the Index Limestone. The general succession, illustrated in Fig. 4, Section 4, agrees closely with that of the Glasgow district, and need not be described in detail.

The *Index Limestone* is exposed on the north side of the St. Flanan basin against the fault at Queenzieburn, the section showing—sandstone up to 45 ft., blaes 20 ft., limestone 4 ft. It is here much baked by contact with the dolerite sill upon which it rests, but the abundant examples of *Productus latissimus* which it contains are still quite recognizable. The Index was at one time exposed in quarries near Braes of Yetts[1] and Easterton,[2] and also in the burn near Woodilee Asylum, but these sections are no longer visible. The average thickness of the seam over a number of bores is 4 ft., the minimum being 3 ft. 5 in., and the maximum 7 ft. 3 in.

The *Bishopbriggs Sandstone,* which is separated from the Index Limestone by 20 to 30 ft. of dark blaes, is exposed in a quarry close to the outcrop of the dolerite sill, immediately north-west of Queenzieburn, where 45 ft. of white freestone is seen. Old quarries in the same rock may be seen near Gartshore House. It is well developed in many of the bore sections, and in some cases is over 60 ft. thick, but in others is broken up into thin posts by intercalated shaly bands.

The *Chapelgreen Coals*, a group of thin seams, 1 to 2 ft. thick, which lie between 28 and 35 fms. above the base of the group, were at one time raised in two shallow pits to the north and west of the Dumbreck shaft, and the "Upper" coal, 2 ft. 2 in., worked 29 fms. from the Index at No. 2 Pit, Meiklehill, may be considered as belonging to the same group. The thin limestones that intervene between the Index and the Calmy seams are in this district two or three in number, and represent the Lyoncross and Orchard Limestones of the Arden basin south of Glasgow. One of these limestones can be seen in the burn section between Milton and Banks, but its horizon is uncertain. The Giffnock Sandstone, which in the area south of the Clyde lies between the Lyoncross and the Orchard, is also sometimes represented in the Kirkintilloch district.

The *Calmy Limestone*, with the underlying *Shirva* or *Hirst Coal*, extends continuously from Torrance to Milton, and thence round the Alton and St. Flanan basins till it is truncated, a little to the south of Shirva, by the St. Flanan fault.

The only locality where the Shirva Coal and the Limestone can be seen in natural section is in the stream between Milton and Banks, where they are brought up between two faults. The section here shows—

		Ft.	In.
Calmy	Limestone	2	0
	Blaes	1	6
	Limestone	2	0
	Blaes and Ironstone (the blaes contains *Edmondia punctatella*)	4	0
Shirva Coal		3	0
	White fireclay		

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[1] Half a mile west of Gartshore House.

[2] Nearly ⅔ of a mile slightly E. of N. of Gartshore House.

The Shirva Coal was at one time worked in a pit one-third of a mile east of Shirva, where the section was as follows :—

		Ft.	In.
CALMY	LIMESTONE	2	6
	Calm	3	6
	LIMESTONE	3	0
	Blaes and IRONSTONES	14	0
SHIRVA	COAL	2	6
	Partings	0	2
	COAL	3	10
	Fireclay	4	6
	Kingle	2	6
	Wild Parrot	0	7
	Blaes and IRONSTONES	25	0
LOWER OR SMITHY	GAS COAL	0	5
	SMITHY COAL	0	8
	Freestone		

The Shirva Coal has also been worked at No. 2 Shaft, St. Flanan, where the seam was 4 ft. 9 in. thick.

The outcrop of the *Castlecary Limestone* around the small outlier of Millstone Grit in the centre of the Shirva basin is concealed beneath the deep surface deposits, but it was proved in the Wester Shirva bore, where the seam, 6 ft. thick, lay 85 fms. above the Calmy Limestone. At two horizons between the Calmy and Castlecary Limestones limy fakes have been recorded (Fig. 4), and probably represent Nos. 1 and 2 limestones of the Plean district.[1] The total thickness of the Upper Limestone Group in the St. Flanan basin is estimated at approximately 220 fms.; the strata actually proved in the Wester Shirva bore amount to 240 fms. (exclusive of 13 fms. of dolerite), but the thicknesses given in the journal are probably increased by the dip of the beds being at a considerable angle. C. B. C., M. M.

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[1] *Cf.* p. 74.

CHAPTER V.

CARBONIFEROUS (*continued*).—MILLSTONE GRIT.

THE Millstone Grit occupies a comparatively small area on the Glasgow District Map, and it is only in the narrow strip that extends through the centre of the City to the north-eastern suburbs, where it is cut off by the Comedie fault, that the whole thickness of the formation is represented at the surface. On the north side of the Comedie fault the Millstone Grit reappears nearly four miles to the east, and between Steps and Garnqueen[1] occupies a shallow syncline, known as the Garnkirk basin; its northern margin along this tract is largely defined by the Garnkirk fault.

Continuous sections of the rocks of this series are nowhere exposed, and not very much is known of the character and sequence of the group as a whole. The records of the exposures at one time visible along the Union Railway, between Burnbank and Garngad Road (*see* below, p. 83), and the quarry sections at Blochairn, Garngad Road and Germiston are the chief sources of our information regarding the tract of Millstone Grit that falls within the City boundaries. The few borings—chiefly for water—that cut rocks of Millstone Grit age in this area are not very reliable, and are difficult to interpret. Further south the recent underground bore at Govan Colliery, referred to below, furnishes a very valuable section of the Millstone Grit as developed underneath the Coal Measures of the Rutherglen district. In the case of the Garnkirk basin, however, where an important fireclay industry has long been established, our knowledge of the sequence of the lower part of the Series, as proved in mines, shafts and borings, is much more complete. For details the reader is referred to the descriptions given under the district headings below. L. W. H., M. M.

Conditions of Sedimentation.—The fossil evidence obtained up to the present time from the Millstone Grit is entirely in favour of regarding the formation as of marine origin. The thick encrinital limestone of Castlecary represents the probable maximum depression of the sea-bottom during Upper Carboniferous Limestone times, and was formed in clear and moderately deep water. The character of the succeeding terrigenous strata of the Millstone Grit indicates that they were for the most part laid down in the open sea, but within a sufficient distance of the shore line to be influenced by tidal currents, and possibly also by the surface carry of large and rapid rivers. The effect of such currents is shown in the violent false-bedding of the sandstones, the erosion of the finer deposits, and the rapid alternation of fine and coarse material, together with the abundance of drifted tree-trunks and other plant remains in the sandstones. The intercalation of the finely divided siliceous muds, represented by the fireclays, with the coarse sandstones suggests, however, oscillations of surface and the recurrence of phases of deposition in land-locked still waters, followed by the irruption of strong currents and a return to open-water conditions.

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[1] Garnqueen lies a short distance beyond the eastern margin of the sheet.

There is some evidence to show that even the few coal seams found in the Millstone Grit of this area are sedimentary in origin. At one locality, a short distance beyond the limits of this map, the thin coal beneath the "Roman Cement" is separated from the underlying fireclay by a thin layer of loose sand containing streaks and laminæ of coaly material.

The general increase in the coarseness of the deposits towards the top of the series points to an excess in the rate of deposition over that of depression, while the consequent shallowing of the water and the oncoming of estuarine and deltaic conditions, is indicated both by the nature of the deposits and by the gradual appearance of estuarine forms in the lowest beds of the Coal Measures. L. W. H.

Variations in Thickness.—The Millstone Grit is defined as including the strata between the top of the Castlecary or Levenseat Limestone and the Crofthead Slatyband Ironstone. Unfortunately neither of these horizons is persistent over the Central Coalfield, and in many localities the lower[1] and upper[2] limits of the Millstone Grit can only be approximately determined. An account of what is known of the development of the Castlecary Limestone within the limits of the Glasgow District Sheet is given on pp. 75 and 79, while for the base of the Coal Measures reference should be made to the evidence outlined in Chapter VI.

The thickness of the Millstone Grit in the immediate neighbourhood of Glasgow is not definitely known. Perhaps the most exact record is that furnished by a diamond boring put down in 1913-14 by Messrs. Wm. Dixon, Ltd., from the workings of their No. 5 Pit, Govan Colliery, near Rutherglen. This boring cut the "Roman Cement" (*see* below, p. 82) at a depth of 230 fms. from the surface, and continued 4 fms. lower, but stopped at this point without reaching the Castlecary Limestone. The lowest coal cut in the upper part of this bore has been taken as the base of the Coal Measures, since massive sandstones, with pebbly bands, such as characterize the Millstone Grit, were entered immediately below. The base of the Coal Measures cannot reasonably be drawn at any lower horizon and the minimum thickness of Millstone Grit strata at this locality—from the coal mentioned to the base of the bore—is 336 ft.[3]

There is no good evidence for the thickness of this series in the Glasgow Green area. The boring for water at the works of Messrs. Paterson & Sons at Charlotte Street (east end of Greendyke Street) has been referred to in a previous chapter (p. 75). This boring records :—

	Fms.	Ft.	In.
Surface deposits (clay, sand and gravel)	19	2	0
Strata, chiefly sandstones and fireclays	30	4	5
Fakes, strong, light	0	2	8
LIMESTONE (? CASTLECARY)	1	3	6
Sandstone, dark, calcareous	2	0	0
LIMESTONE, sandy	0	1	9
Conglomerated stone (angular fragments)	2	4	3

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[1] *See*, for example, 'Economic Geology of the Central Coalfield,' *Mem. Geol. Surv.*, Area IX., 1921, pp. 40, 72, 76, 78 ; and Area VI., 1924, pp. 55, 66, 71, 73.

[2] *See*, for example, *ibid.*, Area VI., 1924, pp. 81-3 especially ; also Area IX., 1921, Index, under Coal Measure Series.

[3] For further details *see* 'Economic Geology of the Central Coalfield,' *Mem. Geol. Surv.*, Area VII., 1920, pp. 13-14, and Plate iii.

The last item is perhaps a fault-rock. On the assumption—rather a doubtful one—that the 9½-foot limestone represents the Castlecary, the thickness of Millstone Grit rocks actually proved here is approximately 187 ft. The full thickness is no doubt considerably more.

Pit sections in the neighbourhood of Blochairn Quarry indicate a minimum thickness of 200 ft. (*see* below p. 85).

In the deepest part of the Garnkirk basin about 280 to 300 ft. of strata of Millstone Grit age are represented, but the higher beds are absent here. That the Millstone Grit is thinning in a south-easterly direction is indicated by the results of the deep diamond boring (Gartsherrie Bore)[1] put down near the east end of Woodend Loch. Although the exact positions of the top and bottom of the Series are somewhat uncertain, the most probable interpretation of this bore shows a thickness for the Millstone Grit of 276 ft. The deep Burnlip boring, situated a short distance south-east of Glenboig Station, also passed from Coal Measure strata through the Millstone Grit into the Carboniferous Limestone Series. Here again the upper and lower limits are somewhat uncertain, but the full thickness of the Millstone Grit is not more than 320 ft.[2] To the north-east of Glenboig, however, it is known to increase ; in the Slamannan district it varies from 516 to 642 ft. approximately, while at South Drum, 1 mile south of Bonnybridge Station (on the L.N.E., Edinburgh to Glasgow main line), it reaches nearly 760 ft.

Lithological Character.—The Castlecary Limestone, like most of the Carboniferous limestones, is overlain by a bed of dark blaes with ironstone nodules, which forms the base of the Millstone Grit. In certain parts of the Central Coalfield a thin oil-shale—the *Levenseat Shale*—occurs on the top of the Limestone, and has proved a useful feature for correlation purposes.[3] It has not so far been recorded at any locality within the Glasgow District Sheet. A white sandstone, of some value as a moulding sand, usually succeeds the blaes, but is often interrupted by intercalations of fakes and fireclay.

At a distance above the Castlecary Limestone, which appears to vary from 4 to 7 fms. approximately, occurs a calcareous band crowded with marine fossils, to which the name "*Roman Cement*" has been given. This band is now known to have a very wide distribution throughout the Central Coalfield, and is generally a readily recognizable horizon in the deep bores that have been put down in recent years to test the Limestone Coals. It occurs typically as a rather dark-coloured shell-cake or "lumachelle," characterized by abundant Orthotetid remains. The shells are usually much broken and flattened, but where determinable specimens have been obtained, they are generally species of *Derbya*. The lower part of the band is frequently described as an impure limestone or "cement." There are not many definite records of it within the limits of the Glasgow District Sheet. As cut in the boring already referred to at Govan Colliery it showed :—

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[1] *Cf.* p. 92.

[2] For a complete journal of the Gartsherrie Bore, *see* R. W. Dron, 'The Coalfields of Scotland,' 1902, pp. 351-360, or 1921, pp. 36-46. For the Burnlip Bore, *see* 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, pp. 28-30 ; 2nd edition, 1925, pp. 40-42.

[3] *See* 'Economic Geology of the Central Coalfield,' Area VI., *Mem. Geol. Surv.*, 1924, pp. 31, 44.

	Ft.	In.
Hard dark blaes, with *Lingula* and small lamellibranchs; the lower two feet with Orthotetids also	8	3
Hard limy blaes crowded with Orthotetids and *Myalina verneuili*	0	6
Parroty blaes, with fish scales, etc.	0	4
Rough, dark, and hard irony dolomite, with finely broken crinoid and brachiopod debris (ROMAN CEMENT) . .	3	0

In two recent borings in the Garnkirk district it is represented by a bed of shelly blaes, 1 ft. or so thick, containing *Lingula* and crushed Orthotetids, and lying 4 fms. or so above the base of the Millstone Grit. The deep Burnlip bore of 1907, to the south-east of Glenboig Station, records the following section of the same horizon :—

	Ft.	In.
LIMESTONE (*i.e.* shelly calcareous blaes) with abundant crushed Orthotetids	2	6
Dark blaes with *Lingula*	0	6
LIMESTONE (*i.e.* shelly calcareous blaes)	2	3
COAL	0	9

These sections illustrate the somewhat variable development of this horizon. Over the remainder of the district described little or nothing is known about its character or faunal contents. In the Garnkirk-Glenboig field the older borings record it merely as "cement," "cement limestone," or in some cases as "limy ironstone." It forms a valuable index-horizon from its relation to the fireclays which give the Millstone Grit of this part of Scotland its economic value. The Lower Fireclay, the seam now principally wrought at Heathfield, Glenboig and Castlecary, lies at a distance varying in different localities from 12 to 30 ft. above the "Cement."

The upper part of the Millstone Grit is largely made up of thick-bedded, white, grey or yellowish sandstones. These are frequently coarse or gritty in texture, with pebbly bands containing well-rounded fragments of white quartz up to half an inch or more in diameter. Intercalations of blaes and fireclay divide the massive sandstones, and some of these higher seams of fireclay are locally of sufficient thickness and quality to be of economic value; one or two of them have been wrought in former years at Blochairn and Garnkirk, and a clay about 27 fms. above the Lower Fireclay has been worked at Gartverrie.

(a) *Glasgow City and Suburbs.*

Excellent sections of almost the whole of the Millstone Grit, as developed within the City boundary, were at one time exposed along the line of the Union Railway, between Burnbank and Garngad Road Station. Very little of these sections is now visible, but they have fortunately been described with great detail in the valuable paper contributed by Mr. James Neilson to the Transactions of the Geological Society of Glasgow in 1875[1] and to which the reader is referred for further information.

The sandstones and shales, with a thin bed of white trap, which can still be seen in the cutting at Burnbank between the Coventry

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[1] 'Geological Notes on the Cuttings in the City of Glasgow Union Railway between Bellgrove and Springburn,' *Trans. Geol. Soc. Glasg.*, vol. v., 1877, p. 222

Drive Bridge and the Monkland Canal, are regarded as the top of the Millstone Grit. In Mr. Neilson's section they are represented as immediately underlying a black shale from which *Carbonicola robusta*, a fossil common in the lower part of the Coal Measures, was obtained. Beyond the canal and outside the Blochairn Steel Works, the railway passes through a cutting in which thick, somewhat calcareous sandstones, faulted near the tunnel against shales with a thin coal, are exposed for a short distance. The sections between the Blochairn Road Bridge and Garngad Road Station are now to a large extent obscured, but the descriptions given by Mr. Neilson indicate that we are here passing downwards through the lower part of the formation. The cementstone and calcareous shale, from which Mr. Neilson obtained a fine suite of marine fossils,[1] can now only be seen in a small exposure in the gutter on the west side of the siding behind the station. The following list of fossils collected by Mr. D. Tait at this locality may be quoted :—

Lingula mytiloides *J. Sow.*
? Orbiculoidea nitida (*Phill.*)
Cf. Derbya robusta (*Hall*)
Hustedia radialis (*Phill.*)
Productus corrugatus *M'Coy*
Productus *cf.* cora *d'Orb.* (not of British authors)
Productus muricatus *Phill.* (relatively abundant)
Productus scabriculus (*Mart.*)
Aviculopecten clathratus (*M'Coy*)
Aviculopecten, var. of A. tabulatus (*M'Coy*)
Edmondia sulcata (*Phill.*)
Limatulina alternata (*M'Coy*)
Modiola
Myalina verneuili (*M'Coy*)
Posidonomya corrugata *Eth.*
Protoschizodus axiniformis (*Port.*)
Cf. Schizodus wheeleri (*Swall.*)

Among the forms obtained by Mr. Neilson as long ago as 1875 from the Garngad Cement special attention should be drawn to the brachiopods *Productus carbonarius* de Kon. and the streptorhynchoid shell figured by Davidson under the name of *Streptorhynchus crenistria* var. *cylindrica* but subsequently referred by Waagen to the genus *Meekella*. The faunal assemblage is not diagnostic of any particular horizon although the occurrence of these two shells and of *Productus* cf. *cora* d'Orb. suggest a post-Visean age for this cement. While it has been included in the Millstone Grit on the Glasgow District Sheet, and is accordingly described in the chapter dealing with that Series, it must be understood that the fauna, so far as this is known, does not preclude its being assigned a somewhat earlier age. In the absence of any good boring at this locality through the Millstone Grit into the Upper Limestone Group it is impossible to say definitely to which division the Garngad Road Cement belongs.

The Garngad Road Quarry, about 180 yds. east of the station, affords a good section of the beds at a slightly higher horizon than the cementstone position. The quarry is traversed by a fault with a downthrow to south-east, and there are several minor slips and crushes. The following sequence can, however, be established :—

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[1] *Ibid.*; *see also* 'Notes on the Geological Survey Memoir,' *Trans. Geol. Soc. Glasg.*, vol. xiv., part iii., 1913, p. 323.

	Ft.	In.
White sandstone—quarried for moulding sand	40 to 50	0
Black blaes with marine fossils at base	18	0
Parroty COAL	3 in. to 0	6
Black blaes with ironstone ribs and plant-bed	15	0
Hard sandstone (or ganister) and fireclay	12	0
COAL	0	4
Ganister Blaes and fireclay	about 6	0
COAL	6 in. to 0	10
Fireclay Blaes } quarried for brickmaking	about 10	0

From the blaes overlying the top coal of this section *Orbiculoidea nitida* (Phill.), *Lingula squamiformis* Phill., *Lingula mytiloides* J. Sow., and *Loxonema nanum* de Koninck have been obtained.[1] The following plants, identified by Dr. R. Kidston as of Lower Carboniferous *facies*, were collected from the black blaes 1 to 4 ft. below the same coal:—

Aphlebia sp.
Sphenopteris elegans
Rhodea moravica
Calamites sp.
Sphenophyllum tenerrimum
Lepidostrobus sp.
Lepidodendron sp.
Calymmathotheca
Archæocalamites stangeri.

Unfortunately the relationship of this section to the Garngad Road Cement is not proved by any continuous exposure or in any neighbouring bore. There would appear to be little doubt, however, that it lies only a short distance above the cement.

Fifty feet of white sandstone is seen in the working face of the Blochairn Quarry,[2] a short distance further to the south. The sandstone rests upon 12 ft. of dark blaes with fireclay below. A similar thick sandstone and seam of fireclay were formerly worked opencast in the old quarry on the east side of the Blochairn Works, and a pit, sunk to the lower fireclays, passed through four seams at depths of 13½, 23, 28 and 34½ fms. from the surface, indicating a thickness of more than 200 ft. of Millstone Grit strata at this point. In the Germiston Quarries,[3] immediately east of the Star Iron Works, 10 to 15 ft. of hard flaggy grits and sandstones with intercalations of dark blaes overlie a thick white false-bedded sandstone with pebbly bands. A 6-inch coal seam was met with, 25 ft. from the surface, in the excavations for the extension of the iron works. These quarries are disused and are now filled up. Coarse sandstone and pebbly grits are also seen in a small opening on the east side of the Barony Poorhouse. These coarse beds probably lie near the top of the formation. L. W. H., M. M.

Little is known regarding the exact position of the top of the Millstone Grit in this district. A few borings farther east in the Shettleston-Baillieston area enter the upper part of the Series but the actual base of the Coal Measures is extremely difficult to fix. The available evidence is supplied by four bores, namely Mr. Dunn's bore at Foxley, that in the New Swinton Pit, Hallhill, north of Baillieston, that at Garthamlock, and that put down from the presumed Balmoral Coal at Gartcraig, near Millerston. Mr. Dunn's bore passed through a 9-inch coal, 10 fms. below the Balmoral—the lowest workable seam in the Shettleston district—and then continued for 7 fms. in strata mainly composed of sandstone and fireclay. The coal was regarded as equivalent to the Colinburn of Armadale. The New Swinton bore was put down a depth of 50 fms. below the Balmoral Coal, in metals composed mainly of sandstone. It passed an 18-inch coal with 3 in. of parrot in the roof at 9 fms., a 9-inch coal at 11 fms., and a 12-inch coal at 22 fms. below the Balmoral. At a depth of 48 fms. below the Balmoral the bore records 22 in. of slatyband ironstone, too low down to be correlated with the Crofthead Slatyband Ironstone, which is taken as the base of the Coal Measures near Fauldhouse.[1] The Garthamlock bore reached a depth of 55 fms. below the supposed Balmoral position and passed mainly through sandstone with fireclays and small coals. The Gartcraig bore passed through similar strata and reached a coal 25 in. thick at a depth of 22½ fms. below the Balmoral.

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[1] The specimen of *Loxonema nanum* from this locality is described and figured by Wheelton Hind; *see* 'On the Lamellibranch and Gasteropod Fauna of the Millstone Grit of Scotland,' *Trans. Roy. Soc. Edin.*, vol. xlvi., 1909, p. 353, and Plate ii., Fig. 51; issued separately 1908.

[2] For an account of this sandstone, *see* pp. 255, 259.

[3] *See* p. 260.

It is impossible to attempt any correlation from these data, or to determine with any accuracy what horizon should be regarded as the equivalent of the Crofthead Slatyband Ironstone. Comparison with the succession in the Coatbridge neighbourhood, however, would seem to indicate for the base of the Coal Measures a position from 10 to 20 fms. below the Balmoral coal.[2] W. B. W.

(b) *Garnkirk and Glenboig.*

The fireclays that occur towards the base of the Millstone Grit are exceptionally well developed as to thickness, quality and accessibility in the ground to the north-east of Glasgow. Hence within the last half-century an important and ever-increasing industry has arisen in this part of the Central Valley, where several firms, employing a large number of hands, are engaged in producing fireclay goods of every kind. Fireclay was first worked on a large scale at Garnkirk, where it was raised for many years in opencast workings and from pits sunk to a depth of 30 or 40 fms. The principal seams wrought were three in number, and ranged in thickness from 3 to 9 ft. The last of the Garnkirk pits was abandoned about the year 1895. The only localities, within the present area, where the fireclays of the Millstone Grit are now being worked are—Heathfield (The Heathfield and Cardowan Fireclay Co.), and Gartcosh, a subsidiary working of the Glenboig Union Fireclay Co. The well-known works of the latter at Glenboig, as well as those of Messrs. Hurll at Garnqueen and Gartliston, fall just without the limits of the Glasgow Sheet.

The principal seam of fireclay now being wrought at the Heathfield Pit lies 40 fms. from the surface at the shaft, and about 24 ft. above a limy ironstone band which probably occupies the positon of the "Roman Cement" (*see* page 83). The thickness of the seam varies from 10 ft. to 25 ft. as an extreme maximum. A large home and colonial and foreign export trade is done in the fireclay products of the Heathfield Works. The articles manufactured include fire-bricks and blocks for all kinds of furnaces, coke-ovens, gas-retorts, salt-glazed sewer-pipes, chimney-shafts and ornamental bricks. A bed of highly siliceous white sandstone, lying 22 fms. above the fireclay, is ground and mixed with the latter for the manufacture of the most siliceous goods.

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[1] The 18-inch coal was called the Colinburn. May not this seam and the 9-inch coal 2 fms. lower represent the Armadale Ball and Main, the 12-inch coal 11 fms. lower still be the Colinburn, and the 22-inch ironstone represent the Goodockhill or Lower Slatyband? For the latter *see* 'Economic Geology of the Central Coalfield,' *Mem. Geol. Surv.*, Area V., 1916, p. 31, or 2nd edition, 1925, p. 43; or Area VII., 1920, p. 12.—M.M.

[2] *Cf.* p. 108, and *see* 'Economic Geology of the Central Coalfield,' *Mem. Geol. Surv.*, Area V., 1916, p. 35 *et seq.*, or 2nd edition, 1925, p. 48. The distance probably decreases in a westerly direction.

At Gartcosh the Lower Fireclay is found about 12 ft. above the Cement. The Gartcosh clay is not quite so refractory as that of Glenboig though from the same horizon. It is therefore not adapted for the manufacture of the most highly resistant goods such as those produced at Glenboig, but is used, without any admixture of sand, for ordinary fire-bricks, gas-retorts, and tiles. A white siliceous sandstone, lying immediately above the fireclay, is used to a small extent in the manufacture of silica bricks with a lime bond.

The Garnqueen-Glenboig field[1] lies just east of the margin of the Glasgow District Sheet, but a few notes relating to it are included here. The surface position of the base of the Millstone Grit between Lochend House and Glenboig cannot be accurately determined, although the outcrop of the Lower Fireclay is approximately known from borings to the west of Garnqueen, and from exposures between Garnqueen Loch and Woodneuk. A fault with a downthrow to the east of 66 ft. has been proved between Garnqueen and Glenboig, and shifts the outcrop of the clay a little to the north-west. From this point it can be followed northwards by the line of mines along the foot of the Inchnock dolerite escarpment (*see* one-inch Sheet 31) until it is cut off and shifted a mile to the east by the east-and-west fault passing through Leckethill Cottages and Bridgend Farm. It reappears at Greenfoot Quarries, a little to the south of Gain. The Lower Fireclay has been worked from a mine above the New (northern) Quarry and this mine, together with the two quarries, affords a good natural section of the lower part of the Millstone Grit. The sequence is as follows :—

	Ft.	In.
Dark blaes with a few marine shells,	2 ft. to 4	0
Coal	0	3
Fakes and fireclay	2	0
Fireclay with sandy ribs and nodules	10	0
Sandstone	5 ft. to 6	0
LOWER FIRECLAY—mined	8 ft. to 10	0
Gap of a few feet.		
Soft yellow gritty sandstone	at least 4	0
Dark blaes	2	6
Nodular clayband IRONSTONE with Nebraskan fauna	0	3
Dark blaes	1 ft. 2 in. to 1	4
CEMENT, dark-grey, ferruginous, with marine shells	1	6
Blaes and limy fakes	0	8
Fakes and faky fireclay	4	0
Fakes and sandstone	8	9
Soft white gritty sandstone of quarry (moulding sand), at least	30	0

The Castlecary Limestone is taken to be represented at this locality by a thin ferruginous limestone at one time exposed on the east side of the railway at Greenfoot Quarry, a short distance below the thick sandstone. Chief interest in the section attaches to the nodular ironstone in the blaes above the "Cement," since this bed was the first to yield *Prothyris elegans* Meek. and other lamellibranchs identified by Dr. Wheelton Hind[1] as new to Scotland, and considered by him to have a close affinity with the lamellibranch fauna of the Coal Measures of Nebraska and Illinois. These interesting forms, first obtained by Mr. D. Tait in 1905 at Greenfoot Quarry, have since been collected at other localities from horizons low down in the Millstone Grit Series—*e.g.* at Torwood Glen, Plean; the banks of the River Avon near Linlithgow; the Bilston Burn, near Polton, Midlothian; and from various borings. It should be added that some members of this assemblage have also been obtained, within recent years, from lower horizons in the Carboniferous sequence—*e.g.* from the Index Limestone in a bore near Stirling, from the Lower Limestones of Fife, and from the Calciferous Sandstone of Kirkcudbrightshire. As a faunal assemblage, however, it remains characteristic of the lower part of the Millstone Grit.

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[1] For an account of the Glenboig clay, *see* J. W. Gregory, 'The Glenboig Fireclay,' *Proc. Roy. Soc. Edin.*, vol. xxx., 1910, pp. 348-360.

From evidence obtained since the publication of the first edition of this memoir it is now known that several marine horizons, one of which is the "Roman Cement," as defined on page 82, occur in the lower part of the Millstone Grit at different localities within the Central Coalfield.[2] It is clear from the section given that two marine horizons are present at Greenfoot but closer correlation is meanwhile impossible. The Greenfoot "cement" may perhaps represent the "Roman Cement," but if so it is certainly an unusual development of the latter. L. W. H., M. M.

Lower Fireclay: general remarks and analyses.—The Lower or Glenboig Fireclay horizon is persistent over a wide area, but the thickness and quality of the individual beds are subject to considerable variation. This variation in quality renders the production of fireclay goods a very complex process, in which skilled selection and careful manipulation are required in order to obtain the best results. The best fireclays are, as a rule, whitish or pale lilac-grey in colour. That colour, however, cannot be taken as an invariable test of quality is shown by the fact that certain dark clays—such as the "blue clay" of Glenboig—have been found to possess high refractory qualities. Bedding planes, especially in the purer seams, are very indistinct, but elsewhere are indicated by thin layers of sandstone or lines of ferruginous sandstone nodules—"button beds." The clay is, however, irregularly jointed and full of small slicken-sided movement planes running in all directions. These are probably due to shrinking, or possibly to movements acting on a very homogeneous unstratified material of less resistant quality than the rocks above and below.

That these lower fireclays were formed under different conditions from the ordinary, often very impure, "root-beds," "coal-seats," or "under-clays" found beneath coal-seams, is at once evident from their position. They are intercalated with massive, false-bedded sandstones, and though in one or two instances a thin coal is found in association with a seam of fireclay, this is of exceptional occurrence. These fireclays also differ from the under-clays in seldom containing traces of rootlets or other plant remains beyond what might have been introduced as floating material, and appear to have been deposited as fine siliceous muds in still water. Among the minerals included in the clay are quartz, plagioclase felspar in a very fresh condition, hornblende and biotite. The presence of these last three minerals suggests derivation from igneous rocks outside the area.

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[1] *Op. cit.*

[2] *See*, for example, 'Economic Geology of the Central Coalfield,' Area II., 1917, pp. 38-41; and Area VI., 1924, pp. 66-68.

The fireclays of economic value in this region may be briefly described as hydrous aluminium silicates, with a varying but usually very small percentage of fluxing impurities—iron, magnesia, lime, and alkalies. The clay-substance has the optical, chemical, and physical properties of kaolin.

The necessary qualities of a good firebrick are—high refractoriness or power of withstanding a high degree of heat, and freedom from splitting when exposed to rapid changes of temperature. The refractoriness of the clay is therefore the principal quality to be considered, and the determining factor in producing this quality is the chemical composition of the material.

It is found by experiment that the most refractory fireclays are those in which the total amount of fluxing impurities is small and which also contain the least amount of free silica, *i.e.* silica not in chemical combination with the alumina of kaolinite or some other form of hydrous aluminium silicate. The proportion of free silica present in a clay or clay mixture is therefore a matter of great importance, and the selection and mixture of the materials a process necessitating care and expert knowledge. The amount of free quartz is best determined—in the case of mixtures of the better grades of clay where the variations of the ingredients can only be within comparatively narrow limits—by rational analysis. This method gives the percentage of the different mineral compounds present, and affords a better conception of the character of the material from a manufacturer's point of view than does an ultimate analysis.

The following analyses of the Lower Fireclay from five different localities have been carried out for the Survey by Mr. Walter C. Hancock.

"Rational" or "Proximate" Analyses of Fireclays from Heathfield; Star Pit, Glenboig; Inchnock Mine, Glenboig; Gain, and Glencryan.[1]

	Heathfield (Museum No. 844).	Star Pit (No. 845).	Inchnock (No. 842).	Gain (No. 846).	Glencryan. (No. 843).
Clay Substance . .	85·42	79·88	66·20	92·52	82·22
Quartz . . .	13·42	19·75	31·12	7·10	15·54
Felspar . . .	1·16	·37	2·68	·38	2·24
	100·00	100·00	100·00	100·00	100·00

The following ultimate analyses of the same five clays are furnished by Mr. E. G. Radley :—

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[1] Gain Mine, 1 mile N.N.E. of Glenboig Station; Glencryan Mine, 5 miles N.E. of Glenboig, 1 mile E. by N. of Cumbernauld Station.

		Heathfield.	Star Pit, Glenboig.	Inchnock.	Gain.	Glencryan.
Silica . .	SiO_2	50·80	53·19	57·46	45·01	51·30
Titanic oxide	TiO_2	1·45	1·55	2·02	1·52	1·45
Alumina .	Al_2O_3	29·62	28·14	24·70	36·03	29·42
Ferric oxide	Fe_2O_3	3·90	2·84	3·02	1·29	2·12
Manganous oxide	MnO	0·12	0·20	·09	·13	·15
Cobalt and nickel oxide .	$(CoNi)O$	0·03	not found	not found	not found	not found
Barium oxide	BaO	0·04	not found	not found	·02	not found
Calcium oxide	CaO	0·42	0·47	·40	·36	·48
Magnesia .	MgO	0·34	0·36	·40	·37	·49
Potash .	K_2O	0·63	0·14	·18	·23	·18
Soda . .	Na_2O	trace	0·06	·02	trace	·14
Lithia. .	Li_2O	trace	trace	trace	trace	trace
Water at 105° C.	H_2O	1·80	2·17	2·08	2·62	3·09
Water above 105° C .	H_2O	10·34	9·91	9·16	12·17	10·75
Phosphoric acid	P_2O_5	0·05	0·12	·07	·06	·20
Iron pyrites	FeS_2	0·04	0·25	·07	·24	·01
Organic matter .		0·18	0·02	not found	·04	·06
Carbon dioxide	CO_2	0·37	0·64	·64	·06	·25
		100·13	100·06	100·31	100·15	100·09

Results of Physical Tests carried out by Mr. Walter C. Hancock :—

	Heathfield (No. 844).	Glenboig (No. 845).
1. *Tests on the unburnt material.*		
Specific gravity at 15·5° C.	2·68	2·68
Plasticity number	14·3	14·0
Shrinkage on air-drying	3·1%	3·1%
Tensile strength—lbs. per sq. in. . . .	42·	29·5
Texture :—"Clay Substance" . . .	17·08%	36·05%
"Silt"	6·72%	2·39%
"Dust Sand"	8·25%	11·17%
"Sand"	67·95%	50·39%
2. *Tests on the burnt material*—		
Specific gravity, at 15·5° C. of material burnt to 1200° C.	2·66	2·66
Shrinkage, when burnt to 500° C.	3·3%	3·5%
,, ,, 800° C.	4·4%	4·4%
,, ,, 1000° C.	6·0%	6·0%
,, ,, 1200° C.	7·6%	6·7%
Tensile strength burnt to 1200° C.	153 lbs.	110 lbs.
Porosity ,, ,, 1200° C.	5·2%	6·14%
Fusing Point	cone 29	cone 29

Notes on the above Physical Tests.

1. *Plasticity Number.*—This figure is the percentage amount of water, calculated on the dry clay, present in a mass of tempered clay of such consistency that a needle of 1 sq. millimetre area, under a load of 300 grams, sinks to a depth of 4 centimetres in the moistened clay in five minutes.

2. *Texture*, or size of grain.

"Clay substance" includes particles up to a maximum diameter of 0·01 millimetre.

"Silt" includes particles whose diameters are between 0·01 and 0·025 millimetre.

"Dust Sand," particles whose diameters are between 0·025 and 0·04.

"Sand," particles whose diameters are between 0·04 and 0·2 and a little over.

3. *Porosity.*—This figure is the percentage weight of water absorbed by a burnt clay block after immersion for twenty-four hours, calculated on the weight of the block when dried at 100° C.
4. *Fusing-point.*—The test for fusing-point refers to Seger's cones, a series of test-pieces made of mixture of clays with fluxes so graded that they represent a series of fusion-points. According to Ries' classification, the Heathfield and Glenboig fireclays would come under the head of "semi-refractory" clays, whose fusion-point lies between cones 27 and 30 inclusive. L. W. H.

(c) *Bishop and Woodend Lochs.*

The tongue of Millstone Grit to the north-east of Bishop Loch is nowhere exposed at the surface. Its existence is chiefly inferred from the evidence afforded by a bore put down about a quarter of a mile north-west of the north-west end of Woodend Loch. At a depth of 18½ fms. the bore entered a mass of sandstone about 23 fms. thick, with subordinate beds of fireclay and fakes. This mass is believed to belong to the Millstone Grit, and, with the prevailing southerly dip, may be expected to come to the surface a short distance to the north. The northern boundary of this tongue is probably formed by the W.N.W. fault, throwing down to the north, proved in the Woodend and Gartsherrie coal workings.

Below this thick sandstone the bore records the following calcareous horizon :—

	In.
Hard limy rib	3
Blue blaes	5
Hard limy rib	8
Blaes	2
COAL	4

Beneath this follows another mass of sandstone about 90 ft. thick, with subordinate fakes and fireclay, succeeded by about 35 ft. of thin alternating bands.

It is just possible that this calcareous horizon may represent the Roman Cement Limestone.

In another bore, put down 180 yds. west of the north-west end of Lochend Loch to a depth of 64 fms. 2 ft. 3 in. below the Balmoral Coal, no limestone or calcareous bed is recorded. The journal shows :—

	Fms.	Ft.	In.
Free Coal (BALMORAL)	0	2	3
Strata, chiefly fakes and fireclay	8	1	1
Free Coal	0	0	10
Strata, chiefly fakes and sandstone	2	4	11
Soft Ironstone and Coal	0	0	4½
Fireclay and fakes	3	5	3
Strata, chiefly sandstones	3	1	0
Fireclay and fakes	1	5	2
Thick sandstone			

It is very difficult to determine where the base of the Coal Measures should be drawn here, whether at the 4½-inch rib of ironstone and coal, or at the top of the thick sandstone 9 fms. lower. On the latter supposition the thickness of Millstone Grit strata proved is nearly 45 fms. The lower part of the bore contains one or two beds of fireclay and a few ribs or balls of ironstone.

In the Gartsherrie diamond bore,[1] put down by Messrs. James Nimmo & Co., about 200 yds. slightly north of east of the north-east corner of Woodend Loch, the exact position of the base of the Millstone Grit is uncertain. A limy fake at 63 fms. 5 ft. 7 in. is believed, however, to be the "Roman Cement." In the same bore the position of the base of the Coal Measures, is also doubtful. A 3-inch blaes streaked with coal lies about 10 fms. below the Balmoral Coal, and makes a tolerably good boundary between an upper set of thin beds, with a considerable proportion of fakes and blaes, and a lower set consisting mainly of sandstone in thick beds, one as much as 133 ft. If this blaes be taken as the bottom of the Coal Measures we have a thickness of about 40 fms. for that part of the Millstone Grit which occurs above the base of the Cement. How many beds below the Cement should be classed with the Millstone Grit is again a matter of doubt. It seems possible that the blaes, 3 ft. 10 in. thick, about 6 fms. below the Cement, may be in the position of the Castlecary Limestone. On the two suppositions advanced the total thickness of the Millstone Grit in this locality is about 46 fms. C. T. C., M. M.

(d) *Outliers of the Kelvin Valley.*

Two small outliers of Millstone Grit occupy the centres of subsidiary basins in the Kelvin Valley. The one underlies the thick superficial deposits of the Balmore Haughs; the other occurs in the Shirva syncline, about two miles E.N.E. of Kirkintilloch. In neither case are the rocks seen at the surface but a few fathoms of strata above the Castlecary Limestone have been proved in bores put down to the underlying Limestone coals. L. W. H.

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[1] The site of this bore is just beyond the eastern margin of the Glasgow District Sheet. For a complete journal, *see* R. W. Dron, 'The Coalfields of Scotland,' 1902, pp. 351-360, or 1921 edn., pp. 36-46.

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CHAPTER VI.

CARBONIFEROUS (*continued*).—PRODUCTIVE COAL MEASURES AND BARREN RED MEASURES.

THE Crofthead Slatyband Ironstone,[1] typically developed in the Fauldhouse district, has been adopted, wherever it can be recognized throughout the Central Coalfield, as the base of the Coal Measures. Unfortunately it is only of local occurrence as a workable blackband. and over considerable areas is represented by a thin pyritous coal associated with irony blaes. In many districts indeed its position is only approximately known. Within the limits of the Glasgow District Sheet there is no constant easily-recognizable horizon that can be taken as its equivalent, and consequently it is difficult to fix a dividing line between the Coal Measures and the underlying Millstone Grit. The difficulty is increased by the very marked attenuation of the lower part of the Coal Measures on the western side of the Central Coalfield as compared with the eastern ; the distance, for example, between the Kiltongue Coal and the Crofthead Slatyband at Fauldhouse is approximately 80 fms., while at Rutherglen the distance between the Kiltongue and the thin coal taken as the base of the group (*see* p. 81) is only about 40 fms. Further notes on this subject are given below under the district headings.

The lowest coal that can be confidently traced throughout the area covered by the Glasgow District Sheet is the Balmoral Coal.[2] This seam corresponds with the Mill Coal of the eastern side of the Central Coalfield where it constitutes the top member of what is generally known as the Armadale Coal Group.[3] This group includes, in addition to the Mill, the Armadale Ball, Armadale Main and Colinburn or Crofthead coals, with the Crofthead Slatyband at the base. The whole group, as well as the coals themselves, thin in a westerly direction and the latter cannot, as a rule, be individually recognized anywhere within the area dealt with below. M. M.

The upper limit of the Productive Coal Measures has been drawn at the marine band described by Mr. Skipsey,[4] more than fifty years ago, as occurring 53 fms. above the Upper Coal of Glasgow. In later years a marine bed, which probably occupies the same, or nearly the same, stratigraphical position as that recorded by Mr. Skipsey, has been found in other Scottish coalfields,[1] and has proved of considerable service in correlating the strata in the different fields. This is the reason why Skipsey's Band has been adopted as the boundary between the Productive Coal Measures and the Barren Red Measures. It must be admitted that it does not form a well-defined boundary between the grey and red strata, for red beds are certainly found in some localities considerably below it, and the red colour is sometimes not found for 25 fms. above it. Nor does it appear to mark the limit between the Middle and the Lower Coal Measure floras, for Dr. Kidston, some years ago, described from Fifeshire, in a position between 583 and 763 ft. above the probable Fifeshire equivalent of Skipsey's Band, an assemblage of fossil plants which he refers to the Middle Coal Measures.[2] On the other hand, in the Sanquhar coalfield, more recently, characteristic Middle Coal Measure plants have been found at a depth of 15 to 19 fms. below the supposed Dumfriesshire representative of this band.

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[1] For an account of this Ironstone, *see* 'The Iron Ores of Scotland,' *Mem. Geol. Surv.*, 1920, pp. 110-116.

[2] *i.e.* The Balmoral Coal of Coatbridge. *See* p. 101.

[3] *See* 'Economic Geology of the Central Coalfield,' Area VI., *Mem. Geol. Surv.*, 1924, pp. 100-105.

[4] 'On the discovery of Carboniferous Limestone Fossils in The Upper Coal Measures to the East of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. ii., part i., 1865, p. 52. 'On the Range and Occurrence of Anthracosia and other shells in the Coal Measures Eastward of Glasgow,' *ibid.*, part ii., 1866, p. 141.

The following table shows the approximate height of Skipsey's Marine Band above (1) the Ell Coal and (2) the Upper Coal in different localities within the Central Coalfield :—

	Height above Ell.	Height above Upper.
Drumpark (Bargeddie)	about 73 fms.	53 fms.
Motherwell (South Calder) . . .	56 ,,	about 41 ,,
,, (River Clyde)	53 ,,	about 38 ,,
Hamilton.	49 ,,	

The first of these—the locality at which the marine band was discovered by Mr. Skipsey during the sinking of a shaft—is the only one to fall within the limits of the Glasgow District Sheet. The marine band has not yet been recorded from any locality west of those cited, so that the boundary line between the Productive Coal Measures and the Barren Red Measures of the Uddingston, Bothwell, Cambuslang and Rutherglen districts has been taken at its supposed position. The distance above the Ell Coal appears from the table given above to decrease in a southerly direction.[3]

The unconformability which was formerly supposed to exist between the Barren Red Measures and the Productive Coal Measures has not, so far as known, been proved in any part of the area included in this map.[4]

In the description of the lithological characters of the strata, an account of their general development in the following districts will be given :—

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[1] J. Smith and C. T. Clough, 'The Marine Beds near the Base of the Upper Carboniferous Red Barren Measures of Scotland.' Summary of Progress for 1907 *Mem. Geol. Surv.*, 1908, p. 127. Since this paper was written a marine band of much the same type, and it is believed in the same position, has been detected in borings in the Douglas Coalfield.

[2] 'On the Various Divisions of the British Carboniferous Rocks as determined by their Fossil Flora,' *Proc. Roy. Phys. Soc. Edin.*, Vice-President's Address, 1893, vol. xii , 1894, p. 204.

[3] For information regarding the exposures of Skipsey's Marine Band in the Motherwell and Hamilton Districts, *see* 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, pp. 66-7, 100.

[4] *Cf.* C. T. Clough, 'The Stratigraphical Relations between the Upper Carboniferous Red Barren Measures of Scotland and the Productive Coal Measures.' Summary of Progress for 1909, *Mem. Geol. Surv.*, 1910, p. 77. From his review of the evidence then available, Dr. Clough concluded that 'no break of importance is as yet known at the base of the Upper Carboniferous Red Barren Measures.' It may be added, however, that recent work in the Alloa district shows that there may here be an unconformable junction between the two groups.

(a) City of Glasgow.
(b) Rutherglen.
(c) Cambuslang, Uddingston and Bothwell.
(d) Shettleston and Baillieston.

J. S. G. W., M. M.

(a) *The City of Glasgow.*

The Crofthead Slatyband Ironstone, which, as already indicated, is taken in the district of Fauldhouse as the base of the Coal Measures, has not been recognized within the City area. Dr. Grossart many years ago stated that fossil brachiopoda are found in this ironstone,[1] and it seems very possible that a thin band of marine blaes, detected by Mr. Neilson some years ago, in the excavations for a deep sewer in Alexandra Parade,[2] near the centre of the northern edge of 6-inch Sheet Lanark 6 S.E., may be on the same horizon. Mr. Neilson described three fossiliferous bands in this locality, the highest full of plant remains, the middle containing *Carbonicola aquilina* and *C. robusta*, while from the third, 1 in. only in thickness, he obtained a number of marine forms (*see* p. 130).

Excellent sections of strata belonging to the lower part of the Coal Measures were at one time exposed along the line of the Union Railway between Burnbank and Garngad Road Station, and these have been described in a valuable paper by Mr. Neilson.[3] Near Burnbank Bleachfield he describes a section showing sandstone, shale (blaes), white trap and columnar coal, 8 in. thick. One of the beds of blaes, hard and containing *Carbonicola robusta*, he refers to a low part of the Coal Measures.

The thin coals and fireclays proved some years ago in a number of shallow bores around Blackhill and Riddrie probably represent the position of the Armadale Coals (*see* p. 93), near the base of the series. The outcrop of one of these coals, 9 in. thick, below a thin bed of white trap, can be seen in the railway cutting north of Provanmill Distillery. A pit shaft, sunk to a depth of 25 fms. on the south side of the Provanmill-Smithy Croft road just east of the quarry, passed through the following seams :—

	Thickness.			Depth from surface.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
COAL . . .	0	0	11	3	0	0
Fireclay . .	0	1	6			
COAL . . .	0	0	11	10	0	0
Fireclay . .	0	2	6			
COAL . . .	0	0	3	16	0	0
Fireclay . .	0	1	0			
COAL . . .	0	1	7	24	0	0
Fireclay . .	0	5	0	24	5	0

The lowest of these seams was formerly worked as the Kiltongue Coal,[4] but is now considered to be the Balmoral, 29 fms. or so below the Kiltongue. Similarly the coal at one time wrought in shallow pits at Riddrie Park (Lethamhill and Hogganfield Pits, abandoned 1902) under the name of the Virtuewell, is now regarded as the Kiltongue. The section here shows :—hard sandstone 24 ft., blaes 2 ft., coal 1 ft. 10 in., fireclay, 1½ ft.

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[1] 'On the Upper Coal Measures of Lanarkshire,' *Trans. Geol. Soc. Glasg.*, vol. iii., part i., 1868, p. 96. *See* also 'Explanation of Sheet 31,' *Mem. Geol. Surv.*, 1879, p. 74.

[2] Account of Proceedings for May 6, 1897, *Trans. Geol. Soc. Glasg.* vol. xi., part i., 1898, pp. 147, 149.

[3] 'Geological Notes on the Cuttings in the City of Glasgow Union Railway between Bellgrove and Springburn.' *Op. cit.*, vol. v., 1877, p. 222.

[4] On plan of workings, dated 1884, and deposited at Home Office, the thickness given is 16 inches. On the revised six-inch Sheet Lanark 6 N.E., it has been called the Armadale Main, but this is probably incorrect.

The Drumgray Coals, which lie between the Kiltongue and the Balmoral seams, have not been recognized as workable coals in the Riddrie area. They are still wrought at Mount Vernon and Calderbank, three miles to the south-east, but thin out to the north-west, and at Gartcraig hardly exceed a foot in thickness. The Kiltongue, a 34-inch seam at Tollcross, also appears to thin out to the westward, and has not been worked within the City boundaries, where there is no good evidence for fixing its position.

The whole of the principal upper seams, from the Splint and Virgin to the Upper Coal, have at one time or another been worked in the eastern part of the City, and the position of their outcrops beneath the ever-growing eastern suburbs can be expressed upon the map with tolerable accuracy.

In a report on the coals beneath Glasgow Green supplied to the Corporation in the year 1857, by Mr. Ronald Johnston, M.E., the seams underlying the southern portion of the Green, near Rutherglen Bridge, are given as seven in number, their thickness and depth below the surface being as shown in the following table :—

	Thickness.		Depth from surface.
	Ft.	In.	Fms.
7. "Mossdale" (Upper Coal)	4	6	54
6. Rough Ell (Ell)	3	6	66½
5. Rough Main (Main)	4	0	73
4. Humph	2	6	86½
3. Splint Ell	3	9	96
2. Splint Main	5	0	98
1. Sour Milk or Virgin	1	8	108

There is, however, some confusion here between the three lower coals, No. 2 being probably the Virgin, and No. 1 a lower seam, possibly the Blackband Coal. At the Farme Colliery, a short distance to the west, the section is as follows :—

	Depth. Fms.
7. Upper Coal	31
6. Ell	41
5. Main	49
4. Humph	57
3. Splint	67

Within recent years the Virgin and Kiltongue coals have also been raised at the Farme Colliery mentioned above. L. W. H.

(b) *Rutherglen District.*

The Coal Measures near Rutherglen are bounded to the south-west by a branch of the large Dechmont Fault. Mining has been active for over two centuries, so that the thick coals, down to the Splint, are practically exhausted. The Kiltongue Coal was for a long time regarded as the lowest workable seam, and although several bores had been sunk through lower strata, their evidence was conflicting. A better knowledge of the sequence has now been attained, and work has been begun in at least one lower seam.

GENERAL SECTION OF COAL MEASURES OF RUTHERGLEN DISTRICT.

	Thickness. Fms.	Ft.	In.	Depth. Fms.	Ft.	In.
Strata, mostly red sandstones, with bands of variegated marl	30	0	0	30	0	0
(Conjectural position of Skipsey's Marine Band)				30	0	0
Reddish grey and white sandstones, with partings of blaes and coal streaks	30	1	6	60	1	6
UPPER COAL	0	4	6	61	0	0
Strata	3	4	7	64	4	7
COAL	0	1	5	65	0	0
Strata, with a soft "Musselband" in centre	8	1	0	73	1	0
ELL COAL	0	5	0	74	0	0
Sandstone with a hard "Musselband" (the Cambuslang Marble) in centre	5	1	3	79	1	3
MAIN COAL	0	4	9	80	0	0
Strata, mostly sandstone	7	3	6	87	3	6
HUMPH COAL	0	2	6	88	0	0
Strata	3	5	9	91	5	9
SPLINT COAL	0	3	3	92	3	0
Strata	1	0	0	93	3	0
VIRGIN COAL	0	1	2	93	4	2
Strata	3	0	4	96	4	6
MUSSELBAND COAL	0	1	6	97	0	0
Strata	5	4	10	102	4	10
BLACKBAND COAL	0	1	2	103	0	0
Strata	5	4	4	108	4	4
VIRTUEWELL COAL	0	1	8	109	0	0
Strata	5	4	9	114	4	9
LADYGRANGE COAL	0	1	3	115	0	0
Strata	6	4	0	121	4	0
KILTONGUE MUSSELBAND	0	2	0	122	0	0
Strata	5	0	7	127	0	7
KILTONGUE COAL	0	2	5	127	3	0
Strata	8	3	5	136	0	5
? UPPER DRUMGRAY COAL	0	0	5	136	0	10
Blaes	0	0	5	136	1	3
COAL	0	0	4	136	1	7
Strata	3	1	0	139	2	7
? MID DRUMGRAY COAL	0	0	10	139	3	5
Strata	1	3	7	141	1	0
COAL	0	0	3	141	1	3
Strata	1	0	3	142	1	6
? LOWER DRUMGRAY COAL	0	1	2½	142	2	8½
Strong coaly blaes	0	0	2	142	2	10½
COAL	0	0	4	142	3	2½
Strata	1	2	7	143	5	9½
COAL	0	0	5	144	0	2½
Strata	3	3	6	147	3	8½
COAL	0	0	8½	147	4	5
Strata	3	0	7	150	5	0
COAL	0	1	4	151	0	4
Rib	0	0	0½	151	0	4½
COAL (strong splint)	0	0	4	151	0	8½
COAL (free)	0	0	3	151	0	11½
Strata	1	4	10	152	5	9½
Coaly blaes	0	2	2	153	1	11½
COAL	0	1	2	153	3	1½
Blaes and Sandstone	0	0	4	153	3	5½
COAL	0	0	6	153	3	11½
Strata	3	1	9	156	5	8½
COAL	0	0	1	156	5	9½
Strata	1	5	2	158	4	11½
COAL	0	0	2	158	5	1½
Strata	7	2	4	166	1	5½
COAL	0	0	1½	166	1	7

The upper part of this section is compiled from various sources, among which may be mentioned the section of No. 4 Pit, Govan Colliery. The lower part is taken direct from a bore from the Kiltongue Coal at No. 5 Pit, Govan Colliery. The lowest coal is regarded as the base of the Coal Measures, since massive sandstones, with pebbly bands, such as characterize the Millstone Grit strata, were entered immediately below.[1]

The supposed Lower Drumgray of the General Section is the coal already referred to as now being wrought beneath the *Kiltongue Seam*. The latter is of excellent quality, and averages two feet in thickness over the district as a whole. It was wrought out some years ago in the Wellshot Colliery, and has mostly been taken out to the west of Rutherglen. Considerable areas remain, however, round Farme Colliery, and to the south of Bankhead and Crosshill. The *Kiltongue Musselband*, with its so-called oil-shale, appears to be typically developed in this district, but has never been wrought. A specimen from No. 6 Pit, Govan Colliery, shows the usual parroty blaes, crowded with crushed " mussels " or *Carbonicola*. In sinking this pit to the Kiltongue Coal, the " shale " is stated to have been found 3 ft. in thickness. The *Ladygrange*, the *Virtuewell* and the *Blackband* coals can be recognized in most of the bore journals, but are rarely over 18 in. in thickness. The *Musselband Coal* has been worked in the disused Fishescoates Colliery in two leaves, 8 in. and 13 in., separated by 9 in. of fireclay.

The *Splint Coal* forms a natural base to the group of thick coals, including the *Humph*, *Main*, *Ell* and *Upper Coals*. The Humph is the thinnest of these, being about 2 ft. 6 in. thick. The others are from 3½ to 5 ft. thick. Between the Main and the Ell is a 15-inch limy ironstone, packed with crushed shells of *Carbonicola*, known farther east as the " Cambuslang Marble " (*see* p. 105). Another musselband occurs between the Ell and the Upper Coal, but this is a soft band, the shells being embedded in blaes.

The *Upper* or *Upper Ell Coal* is as well developed near Rutherglen as in any part of the Lanarkshire field, and averages 4 ft. 6 in. in thickness. In the Farme Colliery workings, north of Rutherglen, a remarkable series of sandstone " washouts," or wants, were found in this seam.[2] Two channels were found, one of them about 200 yds. east of the pit-bottom. In the discussion referred to, three channels were noted, but since that time the " Mid " and " East wants " have been proved to run together, forming parts of a curious twisted course, which runs south towards the Clyde Paper Mills, then bends round sharply towards the north, in which direction it dies out. The breadth was about 80 yds. The western channel was more extensive. Passing through the pit-shaft, it ran south-west for over a mile, having been traced at least as far as the 45-fathom fault at the West Quarries. Under Main Street this channel was proved to be 400 yds. wide, a curious little island of workable coal being found in the middle. The coal was frequently " doubled " along the sides of the channel, and was said also to be of better than average quality : at the same time the components of the original seam were repeated in their normal order—Top Coal, parting, Bottom Coal. As seen in the workings, the junctions of sandstone and coal were exceedingly sharp and clean.

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[1] *Cf.* p. 81.

[2] *Trans. Mining Institute* (*Scotland*), vol. vi., 1884-5, Pl. xxiv., pp. 234-237, in the discussion on Mr. Barrowman's paper, ' Doubling of the Splint Coal at Swinhill Colliery.'

They were also very irregular, narrow tongues of sandstone frequently projecting into the surrounding coal. It is reported that stone mines driven through the want found the sandstone coarse and pebbly at its base, as if it marked the bed of a stream.

The overlying measures are not seen in stream sections, and can only be partially studied in quarries which are now disused. Our knowledge of their character is chiefly derived from the records of bores and pit sections. These show that the strata are mostly red and grey sandstones, with partings of white and variegated marl, and containing some black blaes with coals which are not over 10 in. in thickness. In the journal of No. 5 Pit, Govan Colliery, a " marble band " is recorded at a height of 30 fms. above the Upper Coal. This may perhaps be Skipsey's Marine Band, of which, however, we have no certain knowledge in this district.

Sandstones have been wrought in quarries at Stonelaw, Eastfield and West. Eastfield Quarry affords the best section, and is further referred to on page 256. The sandstone at this locality lies approximately 40 fms. above the Ell, while those at Stonelaw and West are about 10 fms. lower and higher respectively. R. G. C.

(c) *Cambuslang, Uddingston and Bothwell.*

The Uddingston and Bothwell District contains the deepest part of the Central Coalfield. In Hallside Colliery the Upper Coal, which is the highest yet worked in Lanarkshire on any considerable scale, lies at a depth of nearly 200 fms.

In the greater part of the district the Productive Coal Measures are covered by a considerable thickness of Barren Red Measures, which in the colliery just named must amount to about 160 fms. While there is a certain amount of local variation, the following may be regarded as an average sequence for the district.

GENERAL SECTION OF COAL MEASURES OF DISTRICT OF UDDINGSTON AND BOTHWELL.[1]

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Red and purple sandstone and marls . . .	110	0	0	110	0	0
White and brown sandstone, blaes and fireclay, with local reddening, and including from 9 to 16 thin coal seams	79	1	0	189	1	0
Upper, " Wandering " or Mossdale Coal from 9 in. to	0	5	0	190	0	0
Strata, average	7	5	4	197	5	4
Coal	0	0	8	198	0	0
Strata, average	8	5	0	206	5	0
Ell Coal . . . . . from 4 ft. to	1	1	0	208	0	0
Strata, average	3	4	6	211	4	6
Musselband Ironstone (The " Cambuslang Marble ") . . . . from 6 in. to	0	1	6	212	0	0
Strata, average	4	1	0	216	1	0
Pyotshaw Coal . . . from 2 ft. 6 in. to	0	5	0	217	0	0
Strata, average	3	0	6	220	0	6
Main Coal . . . . . from 3 ft. to	0	5	6	221	0	0
Strata, average	7	3	0	228	3	0
Humph Coal . . . . . from 1 ft. to	0	3	0	229	0	0
Strata, average	6	1	0	235	1	0

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[1] ' Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, p. 19.

		Thickness.			Depth.		
		Fms.	Ft.	In.	Fms.	Ft.	In.
SPLINT COAL	from 3 ft. to	0	5	0	236	0	0
Strata, average.		0	3	6	236	3	6
VIRGIN OR SOUR-MILK COAL	from 1 ft. 6 in. to	0	2	6	237	0	0
Strata, average.		10	4	0	247	4	0
BLACKBAND COAL		0	2	0	248	0	0
Strata, average.		9	3	2	257	3	2
VIRTUEWELL OR BENHAR COAL .	from 8 in. to	0	2	10	258	0	0
Strata, average.		8	5	0	266	5	0
KILTONGUE MUSSELBAND SHALE	from 5 in. to	0	1	0	267	0	0
Strata, average.		7	0	6	274	0	6
KILTONGUE COAL . . .	from 6 in. to	0	5	6	275	0	0
Strata, average.		5	4	0	280	4	0
UPPER DRUMGRAY COAL . .	from 1 ft. to	0	2	0	281	0	0
Strata, average.		9	3	6	290	3	6
LOWER DRUMGRAY COAL .	from 1 ft. 6 in. to	0	2	6	291	0	0
Strata, average.		10	0	0	301	0	0
BALMORAL COAL							

In the above section the position of Skipsey's Marine Band, which is taken as the base of the Barren Red Measures, is not indicated, as its occurrence in the district is not known with certainty. Its horizon does not coincide exactly with the change in colour of the sediments, which takes place at different levels in different parts of the coalfield. The estimate of the thickness of Barren Red Measures present at Hallside is made on the assumption that their base lies 50 fms. above the Ell Coal. On the same supposition the underlying Productive Measures have a thickness of about 150 fms. down to the Balmoral Coal. The Coal Measure strata which come below the latter seam in this district are so little known that it would be rash to represent them by a general section. If, however, we take as their base the lowest coal in the Craighead bore, which will shortly be referred to, the total thickness of Productive Coal Measures is about 167 fms.

The coal seams are deepest over a comparatively restricted area in the centre of the district. They rise to all points of the compass, but on the south-west they are soon cut out by the large Dechmont Fault.

Strata below the Balmoral Coal.—A blind bore[1] in Craighead No. 1 Pit (Bothwell district) went to a depth of 92 fms. below the Virgin Coal. Unfortunately no seam below the Blackband can be recognized with certainty, but it seems probable that the bore reached a point some 30 or 35 fms. below the Lower Drumgray. The following section was met with a few fathoms above the base :—

	Fms.	Ft.	In.
Faky sandstone	1	0	0
Faky blaes	0	2	0
COAL	0	0	7
Dark fakes	0	1	0
Blaes	0	0	6
COAL	0	1	6
Dark fakes	0	0	6
Sandstone	1	2	0
COAL	0	0	7

The coals are all too low to correspond with the Balmoral, and the last item may be taken as representing roughly the base of the Coal Measures in this district.

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[1] For a graphic section of this bore, *see* 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, Plate iii., Section 4.

The *Balmoral Coal* (of Coatbridge) corresponds with the Mill Coal of the Armadale-Fauldhouse country, and should not be confused with the Balmoral of the Slamannan district which lies at a somewhat higher horizon and may be correlated with the Shotts Gas.[1] It is probably best developed in the north-western part of the present area in the vicinity of Broomhouse and Carmyle, but elsewhere appears, so far as is known, to be of little or no value.

The *Lower Drumgray Coal* has only been wrought hitherto in the northern part of the Uddingston field. At Tannochside the worked seam measures 30 in. with a blaes roof, and in the middle and southern portions of the Rosehall field (a little east of the edge of the Glasgow District Sheet) averages 32 in. Borings at Haughhead and at Newton No. 2 Pit are supposed to have proved the Lower Drumgray with thicknesses of 24 and 21 in. respectively, but in both cases there is some doubt as to whether a lower division of the coal has actually been reached. At Gateside there appear to be two leaves, 20 and 16 in. thick, separated by 4½ ft. of fakes and blaes. The seam is difficult to identify in the southern part of the area, but at Greenfield Colliery, Blantyre, a 21-inch coal proved 62 fms. below the Virgin Coal is perhaps its equivalent.

The "musselband," which forms a prominent feature a little above the *Upper Drumgray Coal* in most of the Central Coalfield, has seldom been recorded in this district, and identification of this seam is thus rendered sometimes uncertain. It has been worked, for instance, at Broomhouse Colliery under the name of "Under Kiltongue," and at Kenmuir. The section in the latter colliery was :—

		Ft.	In.
Blaes with sandstone ribs		2	0
Dark hard blaes		0	6
Coal	1 ft. 4 in. to	2	0
Fireclay	1 ft. to	2	0

In spite of the difficulty referred to, the seam can be identified in a good many bore sections in other parts of the district. But except at the localities referred to this coal hardly attains a thickness which is likely to make it workable under present conditions, more especially if we take into account its great depth.

The *Kiltongue Coal* can often be identified in borings by the presence a few fathoms above it of a "musselband" accompanied by shale or shaly blaes—the Kiltongue Musselband. In part of the Rosehall field and at Tannochside the seam is split by partings into four leaves ; at the latter locality its total thickness, including three 1 to 3-inch ribs of dirt or stone, is 5 ft. 7 in. At Kenmuirhill the seam was reached by a cross-cut from the Virtuewell workings, and proved to be 2 ft. thick. At Broomhouse Colliery it sometimes exceeds this figure, but the top 2 or 3 in. are often in a "burnt" condition. A recent blind bore at Clydeside found the coal 2 ft. 8 in. in thickness, about 7½ fms. below the Musselband. Bores at Newton and Gateside Collieries respectively record thicknesses of 19 and 18 in. Southwards a blind bore at Greenfield Colliery has proved it to be still thinner, only 15 in.

The *Kiltongue Musselband* is of no economic value in this district, but its importance as an index has already been noticed. In the shaft at Bogleshole Pit (No. 4 Pit, Clyde Iron Works Colliery) the section is :—

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[1] *See* 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, p. 119; 2nd edition, 1925, p. 140.

	Ft.	In.
SHALE	1	0
MUSSELBAND	1	0
Hard stone	0	2
COAL	0	7

There is no coal or shale here between this position and the Kiltongue Coal. The shale and coal on the Musselband horizon are sometimes found in bores in which no "mussels" are recorded. The distance above the Kiltongue Coal varies usually from 3 to 7½ fms.

A thin coal seam has been proved a few fathoms below the Virtuewell in many bores in this district. It may perhaps represent the *Ladygrange Coal.*

In the Uddingston and Bothwell district the *Virtuewell Coal* is often of little value. Neverthless, it is coming to receive more attention, and is being worked at several collieries. As is almost always the case with the seams so far considered, the field of operations is as yet confined to the northern margin of the district. The position is usually less than 10 fms. above the Kiltongue Musselband.

At Clyde Iron Works Colliery the seam is in two leaves, with a parting of fireclay. At Kenmuirhill No. 1 Pit it is also double, the section being :—

	Ft.	In.
COAL	2	0
Faky blaes	2	6
COAL	1	4

At No. 3 Pit, Bredisholm, the seam shows a thickness of 2 ft., and at Tannochside No. 1 Pit a thickness of 2 ft. 10 in. Over the remainder of the district the development is decidedly inferior and nowhere, except possibly at Blantyre, does the seam reach a thickness equal to that of the workable areas to the north.

In contrast to the Virtuewell, the *Blackband Coal* maintains a fairly constant thickness over a large part of the area under discussion. It is worked in various collieries in the marginal or shallower parts of the basin, and in one pit—Dechmont No. 3—not very far from the central or deepest portion. In Tannochside No. 1 Pit the seam shows—blaes with ironstone ribs 2 ft. 4 in., coal 14 in., dirt 9 in., coal 16 in. At Haughhead its thickness is given as 26 in. ; at Gateside No 2 Pit as 24 in. including two 1-inch partings of dirt ; and at Newton No. 2 Pit as a 27-inch inferior coal with hard slaty plies ; these figures are taken from boring records. At Viewpark, near Uddingston, the seam is represented by an excellent house coal, 2 ft. thick, while at Whistleberry the thickness recorded is 21 in. The only part of the district in which the condition of this coal is unsatisfactory—so far as has at present been proved—lies between Carmyle and Broomhouse. A cross-cut at Broomhouse found a foot of wild coal in the Blackband position, while in Kenmuir No. 1 Pit, north of Carmyle, the seam is represented by only 6 in. of coal of a similar description.

No blackband ironstone is in this district included in the seam, and though occasionally, as at Tannochside, the coal is overlain by ribs of clayband, it is not known that any attempt has been made to work them.

A musselband with an underlying coal is often present in this district in the position of the *Musselband Coal and Ironstone*, of which the former has been wrought for instance in the district of Greengairs. The seam, however, is probably not of economic importance in the present area. The " mussels " are often preserved in ribs of limy ironstone occurring at intervals in blaes or parroty blaes, but these ribs, as well as the underlying coal, are too thin and poor to be workable. The position is usually 3 or 4 fms. below the Virgin Coal.

The *Splint and Virgin Coals* are perhaps the two most constant seams in the area both in thickness and quality. They are frequently so near together that they can be taken out in one working, and sometimes, as on the south side of Uddingston, they are only separated by a parting a few inches thick. An average section of the coals in the Whistleberry-Greenfield area may be quoted :—

		Ft.	In.
SPLINT	HEAD COAL	1	6
	SPLINT COAL	0	9
	PARROT COAL	0	4
	FREE COAL	2	4
Stone		0	3
VIRGIN COAL		2	10

Where the seams are separate the Virgin is usually distinctly the thinner. It is classed as a good house coal, but the value is often lessened by the presence of partings of sediment. The Splint Coal is extensively used for furnace purposes. The splint portions come out in big hard blocks which do not readily break up in the furnace under the weight of the overlying material, and the draught is thus kept open. The parting between the two seams is at its maximum in the northern part of the district. At Bogleshole Pit (No. 4 Pit, Clyde Iron Works Colliery), for example, the section reads—blaes and ironstone balls 1 ft. 8 in., Splint Coal 3½ ft., fireclay and blaes 5 ft. 9 in., Virgin Coal 2 ft. 3 in. Sometimes the distance is as much as 12 ft.

In certain sometimes rather sharply defined areas the Splint Coal of this district is so " burnt " as to be unworkable. This applies for instance to Kenmuirhill Colliery, where, however, the Virgin Coal is in part at least quite " clean." Although the point has not been verified, it seems probable that in this, and the other instances which will presently be mentioned, the " burnt " coal is of the calcareous type, and not of the sort which is due to the influence of intrusions.[1] The two varieties have much in common, as they are both softer than ordinary coal, and readily break down into small material. They have both also an unusually high percentage of ash. But the absence of any igneous rock in certain cases compels us to assign the alteration to some different cause.

The *Humph Coal* is best developed in the western and the south-western part of the district. At Bogleshole Pit, the shaft section shows 2½ ft. of coal with a blaes roof and fakes pavement. Sometimes the seam is split by partings of dirt or of stone. Thus a section recorded at Blantyre Colliery gives—blaes with ironstone ribs 3 ft. 3 in., free coal 8 in., stone rib 1 in., free coal 14 in., splint coal 12 in.

The interval between the Humph and the Main Coal is usually 6 or 7 fms., but reaches a maximum in the north-western portion of the district, where it consists almost wholly of sandstone. In the Gateside shaft as much as 13½ fms. of strata intervene between the two seams. The sandstone was formerly quarried in one of the Kirkburn Quarries (south of Cambuslang) and will be further referred to in Chapter XIII., (pp. 256, 262).

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[1] R. W. Dron. 'The Occurrence of Calcareous Coal in a Lanarkshire Coalfield,' *Trans. Inst. Min. Eng.*, vol. xxvii., 1904, p. 92. *See* also 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, pp. 120-121, and Area V., 1916, p. 76; 2nd edition, 1925, p. 93.

The interval between the *Main and Pyotshaw Coals* varies considerably from point to point throughout the area described. They come together, so as to form one working, over most of the Cambuslang-Carmyle district, as well as in parts of the Viewpark field. Where this is the case, the combined seam is known as the Main. Both contain in places separable bands of splinty coal, but this is especially the case with the Pyotshaw, which is in consequence largely selected for blast furnace use. The Main has generally the character of a second-class house coal with a white ash. In some places it contains a layer of inferior gas coal locally known (*i.e.* in No. 4 Pit, Blantyre) as " pugs " which detracts from its value.

The position of the crop is shown by an old day level, which opens on to the Kirk Burn to the south of Cambuslang. The Main and Pyotshaw seams are here in one, with a collective thickness which is stated to be 6 or 7 ft. They are also united in the shaft of Gateside Colliery, though the adjacent workings have more often a section somewhat as follows :—

		Ft.	In.
PYOTSHAW COAL		2	4
Fireclay		1	11
MAIN COAL	COAL	1	10
	Parting	0	3
	COAL	1	2

In the Hallside workings both seams are divided by partings, while the separation between them varies from 0 to 30 in.

At Haughhead Colliery the Main Coal is about 4 ft. in thickness, but the upper part of the section is " burnt " in the way referred to above. The alteration also affects the lower part of the Pyotshaw, which is here somewhat thinner than the underlying seam. At Blantyreferme Colliery the Main Coal has been changed into " strains of coaly matter," while there has also been a certain amount of reddening of the roof. This feature is also associated with the calcareous alteration of the coals in a part of the Rosehall field.[1] The local nature of the " burning " at Blantyreferme is shown by the fact that 300 yds. north-west of the pit bottom the coal had recovered a thickness of 3 ft. 3 in. The Pyotshaw Coal at this colliery comes 4 fms. above the Main with a thickness of 2 ft. 4 in.

In Viewpark Colliery, as already stated, the two seams occasionally coalesce, though in other parts of the field they are as much as 7 fms. apart. The interval is 4 or 5 fms. at Tannochside No. 3 Pit, but decreases again to the north, and is only 6 in. on the north side of No. 1 and 2 Pits.

The strata between the Pyotshaw and Ell Coals in most places in the Cambuslang and Uddingston district consist chiefly of fakes and blaes with sandstone and fireclay bands, but around Hallside and Bothwell Castle these are replaced by sandstones. In many pit sections a thin coal and musselband ironstone, which makes a marked stratigraphical horizon, has been found near the middle of these strata. In the Rutherglen district and at Cambuslang the musselband ironstone is a clayband a few inches thick, and so full of shells of *Carbonicola* that it has acquired the name of the "Cambuslang Marble." This band was formerly used to some extent for ornamental purposes.[1]

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[1] 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, p. 76; 2nd edition, 1925, p. 93.

The *Ell Coal* is, or was, before it became comparatively exhausted, perhaps the most important house coal of the Central Coalfield. It often considerably exceeds the old measure of length from which its name is taken.[2] It reaches its maximum thickness somewhat to the south of Hamilton, and decreases in value from south to north in the area under description. Average sections at Blantyre and Whistleberry Collieries show :—

BLANTYRE.	Ft.	In.
FREE COAL	3	4
SPLINT COAL . . .	0	2
Fireclay	0	5
COAL, often foul . . .	1	6
Fireclay	–	–

WHISTLEBERRY.	Ft.	In.
FREE COAL	1	4
FREE COAL, with splint ribs .	3	10½
Fireclay	0	5
COAL, ribs	0	11
FREE COAL	1	8
Fireclay	–	–

Where best developed, the Ell Coal is generally subdivided into "head", "breast," and "ground" coal. The "head" coal, being inferior to the rest of the seam, has often been left in as a roof to the workings.[3] The same terminology is used at Bothwell Park, East Parkhead, and Douglas Park Collieries lying a little east of the limits of the Glasgow District Sheet, where, however, the three divisions are always separate. The maximum distance between the "breast" and "ground" coals at Bothwell Park is about 2½ ft.; that between the "breast" and "head" coals varies from 3 in. to 27 ft.

At Tannochside Colliery the seam was wrought, on a small scale, from No. 3 Pit, where it had a thickness of 27 in. At Viewpark the section of old workings is :—

	Ft.	In.
Fakes	–	–
WILD COAL	0	6
COAL	1	10
Strong blaes	–	–

At Blantyreferme Colliery the worked seam is 30 in. thick. This does not include a band of inferior or "craw" coal, often about 17 in. thick, and overlying the former at a distance of from 1 to 15 ft. At Haughhead Colliery the workable portion is 36 or 39 in. thick, with a fairly good roof of faky blaes, and with 15 in. of poor coal or coaly blaes immediately beneath. The latter feature is also present at Kenmuirhill, where the section is :—

	Ft.	In.
Fakes	–	–
COAL, free	0	7
,, parrot	0	3
,, free	1	9
Coaly blaes and coal	0	10

The seam has been wrought out at the Clyde Iron Works Colliery (Carmyle and Bogleshole Pits), where it was comparatively shallow, and had the section—free coal 12 in., splint coal 8 in., free coal 6 in., stone 2 in., coal 18 in.

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[1] *See* Ure, 'The Natural History of Rutherglen and East Kilbride,' 1793, p. 262, and 'New Statistical Account of Scotland,' vol. vi., 1845, pp. 422-3. The latter says, 'Of this marble there is a handsome mantelpiece at Chatelherault, near Hamilton, and in the College Library at Glasgow; and at Duddingston, near Queensferry, it has been still more amply made use of.'

[2] The Scottish ell is said to have been slightly more than 37 in. in length.

[3] 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, pp. 96, 117.

The above sections give the impression that the inferior state of the Ell Coal along the northern margin of the area described is partly due to splitting, and partly to the deterioration of the seam. Where "head," "breast," and "ground" coal can be distinguished, the two latter usually make an excellent house coal, while the "head" coal is generally somewhat inferior.

The *Strata between the Ell and the Upper Coal* consist, in the district west of Uddingston, of blaes, sandstone and fakes, while to the south-east, towards Hamilton, they form an alternating series of blaes and fakes. Among them are found several thin coals. A band of ferruginous limestone is known to occur about 3 fms. above the Ell at Hallside Colliery. It is sometimes as much as 9 in. in thickness, and displays very perfect cone-in-cone structure. About 6 fms. higher is a band of "blaes and mussels" which can be traced in a good many bores in the district.

The *Upper, Mossdale,* or *Wandering Coal* is sometimes known as the Upper Coal of Glasgow, as it is best developed in the immediate neighbourhood of that city. All the collieries at present working the coal in this district lie within a radius of seven miles from Glasgow Green. To the east of this it thins, and southwards it becomes unrecognizable with any certainty. Even in the worked area it is not of first-class quality, and the pavement is generally a "bastard" fireclay, so hard that it is necessary to make the holing in the coal itself.

The seam was formerly wrought at the Orion Pit, close to Rosebank Bridge. Here the section was :—

	Ft.	In.
Fireclay	–	–
COAL, foul	0	4
,, clean	1	6
Rib	0	2
COAL	1	0
Rib	0	1
COAL	1	5

At Gateside it is 2 ft. 4 in. thick ; here and at Westburn Colliery, where the seam as a whole is thicker, there is a parrot rib at the base. At Dechmont the total thickness is 3 ft. 4 in., with a 1-inch parting somewhat below the middle of the seam. At Haughhead Colliery it varied from 29 to 34 in., and at Blantyreferme Colliery the workings show 24 in. of coal underlain by 7 in. of wild coal. In the Tannochside and Viewpark fields the Upper Coal is stated to be 20 to 22 in. thick.

In the southern part of the district, as already stated, the position of the seam cannot be recognized with confidence. Two bores in the Blantyre field show the Upper Coal to consist of 6 and 9 in. of foul coal respectively. It is thus rather curious that the coal was wrought at the old Letterick Colliery only half a mile north-west of High Blantyre. There were here 24 in. of clean coal, but the seam included two partings, and 4 in. at the top were described as foul.

The *Palacecraig Blackband*[1] is not known with certainty to occur in the present area. It may perhaps be represented by a 16-inch limy ironstone recorded at Haughhead, 7 fms. above the Upper Coal. A few coals are met with in the interval between the Upper Coal and the base of the Barren Red Measures, but there is seldom any seam exceeding a foot in thickness. Remarkable variations in the strata are known on the north side of the River Clyde in the Uddingston district. Between Fullarton House and Kenmuirhill a bed of sandstone, about 110 ft. thick, lies a little above the Upper Coal. At Tannochside this bed still retains its thickness, but is less homogeneous, being divided by a series of blaes and fakes with three thin coals. About a mile further south, at Viewpark, the section agrees generally with that at Bothwell Castle, and the thick sandstone just alluded to is entirely replaced by alternations of blaes, fakes, fireclays and sandstone ribs.

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[1] *Cf.* p. 117.

Barren Red Measures.—Skipsey's Marine Band, now adopted as the top of the Productive Coal Measures, has so far nowhere been recognized within this district. Taking the base of the Barren Red Measures as lying 50 fms. above the Ell Coal, there must be about 160 fms. of the series represented in the deepest part of the basin. It is composed to a large extent of reddish sandstones, some of which have been extensively quarried.[1] Good sections are exposed in the Clyde west and south of Bothwell Castle and in the Rotten Calder. These sandstones are usually soft, sometimes rather coarse in grain, and blotched in places with streaks and spots of a deep red colour. Not infrequently they contain hard red concretions, up to several yards in length, in which the sand grains are cemented by lime carbonate. Alternating with the sandstones are thick beds of marl or clay, usually described in journals as "fire-clay." A limestone of a compact and usually unfossiliferous type, which is known in other localities to occur not uncommonly in the Barren Measures, is well seen in the South Calder south-west of Orbiston House, and is several feet in thickness. These limestones have not the persistent character of true marine horizons, and do not form good index beds.

Unfortunately our knowledge of these high measures is very incomplete, partly because few complete records of shaft sections of the deeper pits have been preserved. They include types such as the marl referred to, not usually met with in the better-known Productive Measures. This fact has led to a confusion of nomenclature, but even allowing for this, it is probable that the series is unusually variable, both as regards colour and mineral composition. It is interesting in this connection to compare the journals of No. 3 Pit, Bothwell Castle Colliery, and of a bore put down a little to the west of Haughhead Colliery. The two localities are only a mile and a half apart. In the former, no red beds are mentioned at a less distance than 53 fms. above the Upper Coal; in the latter, the colouration begins within 8 fms. of the same coal seam.

The journals just mentioned are the only two in the district which record a limestone above the Upper Coal. At Bothwell Castle a 6-inch limestone is noted 35 fms. above this coal, and at Haughhead a similar rib is found 24 fms. above the same seam. Nothing is known of their character, however, and it is uncertain whether the limestone represents in either case Skipsey's Marine Band. Several coals occur in the lower part of the Barren Red Measures but none of these are likely to be of much economic value.[2]

A mottled purplish marl or fireclay, very high in the Barren Measures, was formerly quarried at the Hallside Terra Cotta Works, about three-quarters of a mile to the east of Hallside Steel Works. The quarry face showed 10 to 20 ft. of surface material, including some brick-clay. This rested on a coarse sandstone overlying the marl referred to. The bed itself was 10 ft. in thickness, and was used for the making of wire-cut bricks. It rested in turn on a quarried sandstone. The latter is a purplish, streaky, fine-grained micaceous rock, lying about 170 fms. above the Ell Coal. J. S. G. W., C. T. C., E. M. A.

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[1] *e.g.*, at Bothwell Park Quarries, about a mile east of Uddingston. For a detailed account of these quarries, *see* W. R. Smellie, 'The sandstones of the Upper Red Barren Measures to the east of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. xiv., part iii, 1913, p. 258.

[2] 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, p. 42.

(d) *Shettleston and Baillieston District.*

This district, broadly speaking, has long ceased to be of much economic importance, the best coals being worked out, and the rest being somewhat difficult of access. In the north there are many sills of the type of dolerite known as teschenite; some of the coals are burnt, and the conditions of mining rendered difficult and uncertain. All the seams from the Balmoral to the Upper are represented in the Shettleston and Baillieston district, but the lowest coal which outcrops is the Kiltongue, the Upper and Lower Drumgray and the Balmoral nowhere coming to the surface. The following is an average section of the strata :—

		Thickness.			Depth.		
		Fms.	Ft.	In.	Fms.	Ft.	In.
Barren Red Measures	about	30	0	0	30	0	0
Skipsey's Marine Band		0	1	0	30	1	0
Strata		53	0	0	83	1	0
Upper Coal	2 ft. 3 in. to	0	4	0	83	5	0
Strata	17 fms. or	18	0	0	101	5	0
Ell Coal	2 ft. to	0	4	6	102	3	6
Strata		7	0	0	109	3	6
Pyotshaw Coal	2 ft. to	0	4	6	110	2	0
Strata, very variable, 0 to 7 fms.;	average say	2	0	0	112	2	0
Main Coal	2½ ft. to	0	4	6	113	0	6
Strata		8	3	0	121	3	6
Humph Coal		0	1	2	121	4	8
Strata		7	0	0	128	4	8
Splint Coal	2 ft. to	0	3	0	129	1	8
Strata, 4ft. to 4 fms.		2	3	0	131	4	8
Virgin Coal		0	2	6	132	1	2
Strata		3	0	0	135	1	2
Musselband Coal		0	1	0	135	2	2
Strata		6	3	0	141	5	2
Blackband Coal, generally in two leaves		0	2	0	142	1	2
Strata, 5 to 9 fms.		7	0	0	149	1	2
Virtuewell Coal, variable, generally thin		0	1	6	149	2	8
Strata, 2 to 5 fms.		3	0	0	152	2	8
Ladygrange Coal		0	0	10	152	3	6
Strata, 5 to 9 fms.		6	3	0	159	0	6
Kiltongue Musselband Shale and Ironstone		0	2	0	159	2	6
Strata, average about		7	0	0	166	2	6
Kiltongue Coal, 20 to 34 in., sometimes in leaves		0	2	4	166	4	10
Strata		3	0	0	169	4	10
Upper Drumgray Coal, 17 to 22 in.		0	1	7	170	0	5
Strata, 7 to 12 fms.		9	0	0	179	0	5
Lower Drumgray Coal		0	1	8	179	2	1
Strata, 10 to 14 fms.		10	0	0	189	2	1
Balmoral Coal	a few inches up to	0	2	8	189	4	9

Skipsey's Marine Band is definitely known only in the eastern part of the district, at Drumpark and Bargeddie (*see* p. 118). The Productive Coal Measures down to the horizon of the Balmoral Coal may be estimated at approximately 160 to 170 fms. From the Balmoral Coal to the base of the Productive Group the distance does not appear anywhere to exceed 20 or 21 fms., and may, locally at least, be as little as 10 fms.

Owing to the exhaustion of the higher coals in the neighbourhood of Shettleston, interest is now centred on the lower seams. The Kiltongue and Drumgray coals are being extensively worked. A still lower coal, the Balmoral, about 27 fms. below the Kiltongue, has been mined at Gartcraig, and proved by shafts in other parts of the district. The occurrence in the body of this coal of a stone rib, which is not easily separable, deteriorates from its value considerably. It was used at Gartcraig for the special purpose of firing bricks manufactured from the underlying fireclay.

Strata below the Balmoral.—A certain amount of information relative to this part of the sequence has already been given on pages 85 to 86, and need not be repeated. The strata below the Balmoral Seam probably form the top rocks in a small tract north of Woodend Loch and in a narrow strip between that loch and the north end of Bishop Loch, but they are covered by superficial deposits.

The journal of the Gartsherrie diamond bore, situated only 80 yds. east of the map margin, records a considerable proportion of blaes for the first 61 ft. below the Balmoral Seam, and three seams of foul coal, or blaes streaked with coal, none more than 4 in. thick, at depths of 32 ft. 43 ft. and 61 ft. below this seam. Below the lowest of these seams there was a 9-fathom bed of sandstone, with some fakes, underlain by a 4-inch seam of coal and blaes, at a depth of 125½ ft. below the Balmoral. The position of the base of the Coal Measures is doubtful. It seems possible that it may be either 61 ft. or 125½ ft. below the Balmoral, or even in some intermediate position, in the thick sandstone.[1]

In a bore put down 180 yds. west of the north-west end of Lochend Loch the Balmoral Seam is recognizable at 28½ fms., and, for 50 ft. below this position, the journal records alternating beds with a considerable proportion of fakes and fireclay, underlain by a 10-inch free coal. Three fathoms below this coal a seam of soft ironstone and coal, 4½ in. thick, was pierced, beneath which no more coal or ironstone was encountered for 35 fms. The top part, about 8 fms. thick, of this barren series contains a fair proportion of fireclay and fakes, and perhaps belongs to the Coal Measures.[2]

In the coalfield of the Kirkwood United Colliery, bores have proved the strata for nearly 50 fms. below the 6-inch coal which seems to represent the Balmoral Seam, but only one lower coal, 6 in. thick, is recorded.

The Balmoral Coal (of Coatbridge) is the lowest seam known to have been worked in the area, but is not a very valuable subject. It is believed to be the same coal as that which further east has been called the Clefted Coal, the Mill Coal, or the Blackhall Parrot.[3] As already stated (p. 95), an old pit which was sunk to a depth of 25 fms. on the south side of the Provanmill Road just east of the quarry worked an 19-inch coal under the name of the Kiltongue Coal. This seam is now considered to be the Balmoral.

In Gartcraig Colliery also the coal worked up to 1919 as the Kiltongue was probably the Balmoral in reality.[4] A bore in No. 1 Pit, Garthamlock, found no coal of any value in the Balmoral position. At Threestonehill, north of Shettleston, an old bore records the Balmoral, 20 in. thick, 24 fms. below the Kiltongue, but the bottom 8 in. was described as "foul." The Springfield bore, put down in an old quarry nearly half a mile E.N.E. of Tollcross, found the same coal, 2 ft. 8 in. thick, at a depth of 24½ fms. under the Kiltongue. It is also known at Foxley, a quarter of a mile S.S.E. of the above quarry, where a pit was sunk to it. It was over 2 ft. thick, but owing to the presence of a brown stone rib (also found at Gartcraig) it could not be profitably worked. Where it has been worked at Lochwood No. 1 Pit, the average section shows—coal 13 in., stone rib 2 in., coal 10 in. It was also raised in Gartsherrie No. 7 Pit at the east end of Woodend Loch, where it was a hard coal with a blaes roof and fireclay pavement, and a parting either of hard white sandstone or of dirt near the middle. In one section near the shaft the parting was 4 in. thick, and each leaf was 13 in. In the Gartsherrie diamond bore, put down 800 ft. north of No. 7 Pit, the thickness proved was 30 in.

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[1] *Cf.* p. 92.

[2] *Cf.* p. 91.

[3] *Cf.* p. 101.

[4] *See* 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, p. 38; 2nd edition, 1925, p. 52.

Three to five fathoms above the Balmoral occurs a seam, generally 6 to 10 in. thick, but locally reaching 2 ft., known as the Balmoral Index.

The Drumgray Coals have not been recognized as workable seams in the Riddrie area. At Gartcraig they hardly exceed a foot in thickness. On the north side of Shettleston and Baillieston also the *Lower Drumgray* is generally very thin or irregular in its development; there are sometimes several small coals near its position. In a recent blind bore, however, near Baillieston House a seam called the Lower Drumgray is recorded as 20 in. In an older bore in the abandoned "New Swinton Pit," near Easterhouse Station, the seam appears to have been even thicker, as much as 31 in. without any parting being mentioned in the journal.

The seam has been extensively worked at Calderbank, Broomhouse, where it is in two leaves, 18 in. and 11 in. thick, separated by a 5-inch parting of blaes. At Burntbroom the thickness is 20 in., and at Foxley the same or rather more.

For a considerable distance east of Baillieston the seam appears to be of little or no value. In the north-western part of the Bredisholm field it is occasionally divided into two leaves by a 2-foot parting. From the information provided by various bores on the north side of the Monkland Canal it seems probable that this parting increases in thickness towards the north, and at the same time the leaves become thinner.

The *Upper Drumgray Coal* is often a hard coal suitable for furnace use. At Riddrie it seems of no value. A little further east, at Shettleston and Baillieston, it is only 3 or 4 fms. below the Kiltongue, and under the impression that it is merely a lower leaf of that seam is sometimes called the "Under Kiltongue." The thickness in this locality seldom exceeds 18 in., but sometimes reaches 21 in. or even more. In the Mount Vernon Colliery, about 2800 ft. N.N.W. of Mount Vernon House, it is in places unusually thick, and has been extensively worked, but is said to be in a burnt condition in certain parts owing to the presence of a thin "float" (sill) of white trap. No "mussels" have been noted in the roof in any of the journals of bores or pit sections near Shettleston or Baillieston, though further east one of the best known musselbands occurs on this horizon. In Lochwood Colliery the section in the workings showed a thickness of 16 in. This 16-inch coal was said to be a tolerably good gas coal, and also a fair coking coal. It was rather hard and splinty, and has sometimes been used in the Langloan Blast Furnaces. In the northern part of the Lochwood field the seam dwindles to 12 or 8 in. and ceases to be workable. A bed of blaes, from 8 to 18 in. thick, overlies the coal and contains scattered specimens of crushed *Carbonicola*. In a special examination of the workings some years ago no regular musselband was detected in the parts accessible to observation. The sandstone above the blaes contains many remains of fossil trees, and gives out a small amount of crude bitumen oozing from joints.

In Ellismuir No. 2 Pit this coal is about 14 in. thick, and in Bredisholm No. 3 Pit it is reported to be 21 in., while in a bore near Heatheryknowe United No. 3 Pit the probable equivalent of the Upper Drumgray lies 8 fms. below the Kiltongue and is only 9 in. thick.

The seam at one time wrought under the name of the Virtuewell at Riddrie Park and at Gartcraig Colliery is now regarded as the *Kiltongue*.[1] The massive sandstone, from 3 to 4 fms. thick, above the so-called Virtuewell at Gartcraig may well be correlated with that commonly found above the Kiltongue Coal : the sandstone above the true Virtuewell seldom if ever attains such a thickness in this neighbourhood.

Near Shettleston and Baillieston the Kiltongue is generally represented by one workable leaf only, 2 or 3 ft. thick, which has been extensively mined, but thin laminae of coal, from 1 to 7 in. thick, are occasionally found just below this. Above the seam is a sandstone, about 8 fms. thick, separating the coal from the blaes and fireclay which contains the Kiltongue Musselband. About Shettleston, Ruchazie and Cardowan this sandstone usually forms the roof of the coal, but further east, at Easterhouse 4 or 5 ft. of blaes intervene. This sandstone does not exist at Lochwood, and the thickness of strata between the Kiltongue Coal and the overlying musselband is there greatly reduced.

In the pits of the Mount Vernon Colliery Co., at Shettleston, the Kiltongue has been extensively worked. This field is wonderfully clean and free from faults, but the roof of the coal is often bad. The blaes in the Kiltongue roof in the neighbourhood of Mount Vernon yields very well preserved plant remains, and has become famous for its many beautiful specimens of ferns.[2]

In Bredisholm No. 3 Pit the Kiltongue Seam is got out in one working, the average section being—

	Ft.	In.
COAL	1	0
Stone	0	2
COAL	1	6
Fireclay	0	10
COAL	3	0

But northwards and westwards the fireclay becomes mixed with fakes and stone, and this parting increases in thickness, so that the two leaves can no more be got out in one working : this is the case, for example, at Lochwood Colliery, where the average section shows—coal 2 ft., on fireclay and blaes 8 to 12 ft., on coal 2½ ft., with a fireclay roof and pavement. The top leaf is not of much value, but the lower leaf is a good house coal over most of the field. Plant remains are abundant in the clayey blaes above the lower leaf at Lochwood. It is probable that in the localities further west of this the position of the upper leaf of the Lochwood Kiltongue is occupied by the thick sandstone already referred to.

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[1] *See* p. 96.

[2] R. Kidston, 'Notes on some Fossil Plants collected by Mr. R. Dunlop, Airdrie, from the Lanarkshire Coal field,' *Trans. Geol. Soc. Glasg.*, vol. viii., part i., 1886, p. 47.

Also 'Natural History of Glasgow and the West of Scotland,' *Brit. Assoc. Handbook, Glasgow*, 1901, p. 468 ; geological portion reprinted 1904 by the Glasgow Geological Society.

The seam is certainly best developed in the eastern part of the map near Coatbridge. Thus in Drumpellier No. 3 Pit it is in three leaves of which the lowest (and thickest) averages about 25 in. In the Drumpellier policies the seam is in four leaves with a total thickness of about 7 ft. of coal.

The *Kiltongue Musselband* usually consists in part of parrot shale which was formerly used for making oil,[1] but it is of chief importance as an index of stratigraphical position, being of very constant occurrence above the Kiltongue Coal at distances varying from 1 to 11 fms. Its " mussels " are perhaps not so closely packed as those in the musselband that comes 6 or 7 fms. above the Airdrie Blackband. They occur both in the parrot shale and in the ironstone ribs that sometimes accompany the shale. Among the fossils the following forms have been identified :—*Anthracomya modiolaris* (J. de C. Sowerby), *Carbonicola sp.* allied to *C. acuta* (J. Sow.), *Naiadites modiolaris* (J. de C. Sowerby).

The Kiltongue Musselband is generally well developed near Shettleston and Baillieston. It lies there from 5 to 10 fms. above the Kiltongue and consists generally of 6 in. of parrot shale on about the same thickness of ironstone. In the Tollcross district it is found 4 fms. above the Kiltongue and shows—oil-shale 12 in., musselband ironstone 12 in., stone 2 in., coal 7 in. In the Kirkwood United field the seam is unusually thick, as shown by the following section :—

	Ft.	In.
Fireclay with 4 ribs of faky ironstone .	2	9
Bituminous Shale	0	11½
Gas Coal	0	3½
Musselband Ironstone . . .	0	10½

The musselband ironstone is about 3½ ft. above a 6-in. free coal, and 5 fms. above the top of the Kiltongue Coal.

In a bore at Lochwood Colliery the Kiltongue Musselband Shale is recorded as 14 in. thick, and only 6½ ft. above the Kiltongue Coal : no ironstone is mentioned in association. Somewhat further east, in a bore 200 yds. west of Woodend Loch, it is about 7 ft. above the top of the Kiltongue Coal, and gives the following section—shaly blaes 21 in., musselband ironstone 3 in., shale 3 in., ironstone 2 in. From information kindly supplied by Messrs. J. W. Ormiston & Sons we know that the musselband ironstone yielded on two trials an average of 16·64 per cent. of iron, while the lower ironstone yielded 11·75 per cent.

The *Ladygrange Coal* is not known to have been mined in any part of the Glasgow district, though it is often recognizable, and at Threestonehill, Queenslie and Comedie is about 15 in. thick. The three lowest coals in the shaft of Comedie No. 5 Pit at Millerston were formerly called the Musselband, Blackband and Virtuewell, but Mr. Thorneycroft considers these names to be incorrect, and supposes the so-called Virtuewell to be really the Ladygrange. Comparison of the section with those in the neighbouring bores confirms this conclusion. The journal of a bore at Lochwood Colliery records nothing that can represent the Ladygrange.

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[1] *See* Special Reports on the Mineral Resources of Great Britain, vol. xxiv., 'Cannel Coals, Lignite and Mineral Oil in Scotland,' *Mem. Geol. Surv.*, 1922, pp. 14-15.

The *Virtuewell Coal* is often very poorly represented in this district but becomes well developed 2 or 3 miles further east, near Airdrie.[1] Near Shettleston and Baillieston the seam is too thin to have been of any economic importance up to the present, and although it thickens a little to the north it seldom seems to exceed 18 in. The thickness mentioned is found at Queenslie. Comedie No. 5 Pit showed two leaves of 6 and 14 in. separated by 12 in. of fakes; this seam was at one time called the Blackband, but it is tolerably certain it is really the Virtuewell. In the section of the Mutton Pit, Tollcross, about 7 ft. above the Virtuewell Coal there is recorded a band of limestone, 22 in. thick, overlain by 2 fms. of blaes with ironstone. This limestone may possibly be the equivalent of that described by Dr. Clough as occurring on this horizon at Dalmacouther and proved also in bores in the neighbourhood of Dykehead, Plains and Meadowhead, near Airdrie.[2] The Virtuewell appears to be poorly developed at Lochwood, but farther east in the now abandoned Woodend and Gartcloss workings, close to the eastern margin of the map, its average section, including three dirt partings, was 4 ft. 6 in.; the top leaf, 2 ft. 11 in. thick, was the only one of value.

At Shettleston and northwards to Comedie and Cardowan the *Blackband Coal* is in two leaves, which together average about 16 in., but in places reach 2 ft.; the parting of blaes and fireclay varies from 2 in. to 3 ft. This seam was worked under the name of the Musselband Coal at Comedie, where it lies 8 fms. under the Virgin, an average section showing:—

	Ft.	In.
Blaes and IRONSTONE ribs	–	–
IRONSTONE, roof	0	3
Fakes and blaes	2	1
COAL	0	10
Sclit	0	2
COAL	1	2
Fireclay	–	–

A bore on Cranhill to the north of Shettleston records the Blackband as 22 in. without any parting. In the neighbourhood of Tollcross and Mount Vernon it is very poorly developed, but it thickens eastwards towards Ellismuir and Bredisholm. At Gartcloss No. 1 Pit and Gartsherrie No. 8 Pit, the workings of which are for the most part just outside the map, a seam formerly worked under the name of the Blackband Coal contains some gas coal at the top, occasionally mixed with a little ironstone. Various types of fossil lamellibranchs occur either singly or in groups in blaes above the coal, and have been named by Dr. Wheelton Hind as follows:—

Naiadites modiolaris (*J. de C. Sow.*)
,, carinata (*J. de C. Sow.*)
? Carbonicola nucularis (*Hind.*)
Carbonicola aquilina (*J. de C. Sow.*)
Anthracomya subcentralis (*Salter.*)

The irony bands which are occasionally developed in the coal also contain pieces of broken fossil shells. Dr. Hind states that the assemblage in the above list is practically the same as that found with the Hard Mine Coal of North Staffordshire.[1] The base of this Blackband coal is 48 ft. above that of the Virtuewell, and 87 ft. below the Virgin Seam.

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[1] The old Holy Well, from which the name 'Virtuewell' is taken, is situated in the glen about half a mile north-west of Commonhead Station, Airdrie.

[2] 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, pp. 95-6; 2nd edition, 1925, p. 114.

The *Musselband Coal and Ironstone* in the Shettleston and Baillieston district lies 3 to 4 fms. below the Virgin; it is thin and impersistent and rarely exceeds a foot in thickness. An underground bore at Greenfield, north of Shettleston, records the following—coal 4½ in., fireclay 7½ in., musselband 4 in., fireclay and fakes 9½ in., coal 9 in. In the Garthamlock field the musselband is recorded in bores as a "shelly blaes," 10 to 15 in. thick, overlying a thin coal. Where best developed however, the "mussels" are sometimes so abundant that they form bands of "marble" several inches thick. Specimens examined by Dr. Wheelton Hind have been referred to the following species: *Anthracomya adamsi* (Salter), *Anthracomya modiolaris* (J. de C. Sowerby), *Carbonicola aquilina* (J. de C. Sowerby), *Carbonicola robusta* (J. de C. Sowerby).

Virgin and Splint Coals.—The Splint Coal is the most constant of the Lanarkshire seams, and in order to show the structure and chief faults more distinctly, it has been taken as a colour boundary on the one-inch geological Map. Its position is slightly above the middle of the Productive Coal Measures. The underlying Virgin or Sourmilk Coal is described with the Splint because the two are sometimes so near together that they are taken out in one working. The hard splinty character of certain bands in the Splint Seam make it specially valuable for furnace purposes. Since as a rule it is the more valuable of the two, it was largely exhausted in most places long ago, while the Virgin has been worked only within comparatively recent years.

To the north of Tollcross and Baillieston, both seams average 2 ft. 6 in., seldom rising above 3 ft. or falling below 2 ft. In Comedie No. 3 Pit the Splint was unusually thin, as shown in the following section:—

	Fms.	Ft.	In.
Sandstone			
Blaes	0	1	6
SPLINT SEAM	0	1	6
Fakes and fireclay	1	5	6
Sandstone	1	2	0
Blaes and sandstone	0	3	0
VIRGIN COAL	0	2	6

In Comedie No. 5 Pit the Splint was rather thicker, 2 ft. 2 in., and the parting between the two seams diminished to 2 fms. In both the above pits a whin float, 15 ft. thick, lies a short distance above the Splint Seam. In Queenslie Colliery the float is thicker and also closer to the Splint, and both coals are described as "blind."

At Gartocher, North Mount Vernon, both the Splint and the Virgin are said to be "burnt." Further east, in the Peasweep Pit, near Barrachnie, they seemed in better condition, the overlying whin float, 15 ft. thick, being more than 6 fms. above the Splint: here the Virgin is 2 ft. 8 in. and the Splint 2 ft. 5½ in. In the Bredisholm field the former maintains a steady thickness of 30 in., while in the Gartcloss and Gartsherrie No. 8 Pit workings the section was—parrot 2 in., coal 5 in., dirt 2 in., coal 20 in., wild coal 2 in. Along this eastern margin of the area described the parting between the two seams varies from 4 to about 12 ft. The Splint in the old workings at Drumpark was 4 ft. 1 in., and at No. 2 Pit, Summerlee Kirkwood, 3½ ft., thick. In the Kirkwood United field many duplications and triplications were encountered, and were accompanied by wants that ran parallel to them; in one place the Splint Seam became as much as 21 ft. thick.[1]

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[1] 'Geology of the North Staffordshire Coalfields,' *Mem. Geol. Surv.*, 1905, p. 313. The Hard Mine is a coal rather below the middle of the Grey or chief coal-bearing Measures of North Staffordshire. It is noteworthy, also, that the two species of *Naiadites* extend down to the base of the Edge Coals (Limestone Coals) of Midlothian; *see* 'Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, p. 220.

The *Humph Coal* is one of the thinner and inferior seams and has not been generally worked. In a blind bore at the Peasweep Pit, Barrachnie, it was found nearly 9 fms. below the Main and 11 fms. above the Splint, but the thickness was only 14½ in. In the Bredisholm field, where a cross-cut mine exposed a section of it, it occurs in two leaves as follows—blaes with "mussels" 4 in., coal 3 in., wild parrot 14 in., blaes and fakes 7½ ft., coal 1 ft. The shells in the roof are abundant but rather crushed, and their names have not been determined.

The *Main and Pyotshaw Coals* are freqently very close together or even coalesce, though in other places they are as much as 7 fms. apart. At Tollcross and in the eastern part of Glasgow (*cf.* p. 104), they appear to form one seam. In the Greenfield area the Main showed an average thickness of 2½ ft., including an 8-inch gas coal layer at the top. Near Provan Hall a big whin float is believed to occupy the position of the Main Coal and to have frequently destroyed or spoilt it.[2] Farther south in the Mount Vernon area an old bore on the site of Burntbroom No. 1 Pit records—Pyotshaw Coal 2 ft., parting 3½ in., Main Coal 2 ft. 4 in. In the west end of the Daldowie workings the parting was again thin, but increased in an easterly direction until it was finally necessary to abandon the Pyotshaw. In the old Springhill workings to the west of Easterhouse again the two seams were separated by as much as 7 fms.; here the Pyotshaw showed—coal 22 in., stone 9 in., coal 3 in., while the Main was 4 ft. Eastwards of this the parting appears to be much less. At Calderbank Pit, south of Baillieston, it was about 2½ fms., while at Bredisholm No. 3 Pit the combined seams show—Pyotshaw 4½ ft., fireclay 2 ft., Main 4½ ft. In the latter field the Pyotshaw is generally divisible into an upper, splint portion, used as a furnace coal, and an under portion of soft coal, about 1 ft. thick. Locally as at Heatheryknowe the Main Coal contains a thin rib of gas coal.

The *Strata between the Pyotshaw and Ell Coals* often amount to 6 or 8 fms. In many parts of Lanarkshire there is near the middle a thin coal and musselband (Cambuslang Marble)[3] that forms an index. In the district being described this index has not been generally noted, but the journal of a blind bore in the old Peasweep Pit, Barrachnie records an 8-inch musselband 2½ fms. above the waste of the Main Coal.

The *Ell Coal* is the top coal generally worked, but in most of the district under description it is thin, and so split into leaves that it is of little value. Mr. Neilson obtained specimens of *Carbonicola turgida* from this horizon in Black Prince Pit, 50 yds. north of the railway 200 yds. west of Shettleston Station, and this fossil is also said to occur at this horizon at Cambuslang. It seems doubtful whether it has yet been found in any lower position.

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[1] Discussion on Mr. James Barrowman's paper on the 'Doubling of the Splint Coal at Swinhill Colliery,' *Trans. Min. Inst. Scotland*, vol. vi., 1884-5, p. 233.

[2] This is the teschenite sill referred to on p. 162.

[3] *See* p. 105.

At Greenfield and Tollcross the Ell is said to have been from 4 to 4½ ft. thick, but at Springhill, north-west of Baillieston, the development was much poorer, as indicated in the following section—coal 21 in., clay 4 in., coal 3½ in. In a bore in Bargeddie Pit the seam is in two leaves, the upper one 1 ft. and the lower 2 ft. 9 in. but foul: the parting of dark blaes is as much as 16 ft.: the distance above the Pyotshaw is about 8 fms. The seam is also in two leaves at Heatheryknowe and Drumpellier, and at the old Gartcloss and Gartsherrie Collieries showed—upper leaf 10 in., fakes and sandstone 5 ft. 2 in., lower leaf 2 ft. 3 in. In the Bredisholm field the Ell, or part of it, is worked as a steam coal, and is of rather inferior quality: the section in the workings is—free coal 21 in., dirt 5½ in., free coal 11 in.

Strata between the Ell and the Upper Coal of Glasgow.—At the old Bargeddie Pit the distance between these coals is 23½ fms., and a 4-inch musselband occurs 7½ fms. below the Upper. In certain places north of the North Calder, too, a musselband and thin coal are found about 40 ft. below the Upper. This band is well exposed on the west side of the Luggie Burn, rather more than two-thirds of a mile south of Drumpark House: here it is 15 in. thick and consists of hard parroty blaes or shale with many remains of badly preserved *Carbonicola*, particularly crowded in the lower half: a few feet below this band is a hard blaes with thin courses of ironstone containing *Carbonicola aquilina* (J. de C. Sow.): below this again is a bed of clayey blaes with plant remains, among which Dr. Kidston has identified *Pecopteris Miltoni*.

The *Upper, Wandering* or *Mossdale Coal* is often called the Upper of Glasgow, as it is best developed near that city. Occasionally it is called the Upper Ell, but this is liable to lead to confusion, as the Ell Coal itself is often divided into upper and lower leaves. It was worked near the crop on the east side of Shettleston where a bore, put down some years ago near the Acme Machine Works, passed through one of the old stoops and found the coal to be 3 ft. 9 in. thick. Bores near Bargeddie record thicknesses of 2 ft. 3 in., and 3 ft. 9 in. It is probable that it is near the crop at the top of the west bank of the Luggie Burn, near Langmuir, and that it extends thence in a westerly direction not far south of the Shettleston fault.

Strata between Upper Coal and Skipsey's Marine Band.—The upper limit of these beds is usually uncertain as the marine band has very rarely been recognized by those engaged in pit-sinking or boring operations. Good natural sections are seen at the following localities: the burn (Luggie Burn) below the railway viaduct a third of a mile south of Drumpark, down to the foot of the burn: the North Calder at and below the foot of the Luggie Burn: the burn that flows into the North Calder, from the south, about a third of a mile north-east of Newlands.

The section in the Luggie Burn, and in the adjacent part of the North Calder, as far down as the prominent bend nearly three-quarters of a mile east of Newlands, may be generalized as shown below, in descending order.

	Fms.	Ft.	In.
Soft coarse red and yellow sandstone	3	2	0
COAL . . . 1 in. to	0	1	0
Fine-grained yellow sandstone	0	3	0
Yellow fakes and dark grey blaes	0	4	0
Gap	7	2	0
Forge Sandstone, soft, massive, rather coarse	9	1	0
Gap	0	5	0
Coarse red and yellow massive sandstone	1	4	0
Bed resembling a conglomerate, with irregular red irony lumps	0	1	6
Red and grey blaes with bands of red and yellow sandstone	3	5	6
Purple, red and grey blaes with some sandstone bands	0	4	0
Red lenticular ironstone rib with *Carbonicola* remains	0	0	1
Reddish purple and grey blaes	0	1	3
Red and buff ferruginous limestone	0	0	2
Blaes	0	0	2
Carbonaceous limestone	0	0	2
Purple and grey blaes with red irony nodules and flaggy sandstones	1	2	0
Red and yellow sandstone, rather massive and with big lumps of calcareous sandstone (lunkers)	6	4	0
Fakes and sandy blaes: somewhat red	2	2	0
Gap	0	5	0
	39	5	10

Probable position of Upper Coal

In the above section the ironstone and limestone ribs, which occur about 11 fms. above the probable position of the Upper Coal, may possibly represent the Palacecraig Ironstone, which at Palacecraig, three miles further east, is 43 or 44 ft. above the Upper Coal.

The Forge Sandstone is well seen in the North Calder just above the Bredisholm Spade Forge. It seems a tolerably constant bed in the Coatbridge district, being well represented in the river section near Palacecraig, three miles east of the Luggie Burn, and also, probably, in the banks of the river just above Newlands House. The gap above the Forge Sandstone is represented in other exposures further west, near the viaduct of the mineral line north-east of Newlands, by beds of blaes, fireclay, yellow fakes, yellow sandstone and several thin seams of coal, none so much as 8 in. thick: some of the beds of clayey blaes contain a number of plant remains, among which Dr. Kidston identified the following:—

Alethopteris decurrens (*Artis.*)
,, lonchitica (*Schloth.*)
Neuropteris gigantea (*Stbg.*)
Mariopteris muricata (*Schloth.*)
Sphenopteris obtusiloba (*Brongt.*)
Sphenophyllum cuneifolium (*Stbg.*)
Calamites undulatus (*Stbg.*)
Cone of Calamocladus equisetiformis (*Schloth.*)
Lepidophloios

On the north side of the North Calder about 500 yds. N.N.E. of Newlands (Cottages) a pale grey clay contains remains of *Lepidophloios acerosus* (*L.* & *H.*), and below this is a 2-inch coal and then a wild parroty blaes with some crushed remains of lamellibranchs. These beds probably come below the Forge Sandstone. C. T. C.

In the shaft section of Bredisholm Pit No. 3, a coal, 22 in. thick, with a parting of 4 in., occurs at a height of 284 ft. above the Upper Coal, while a boring near Bartonshill No. 1 Pit at Bargeddie records a 20-inch seam about 19 fms. above the Upper.

For reasons already stated,[1] *Skipsey's Marine Band* has been adopted as the upper limit of the Productive Coal Measures. It was pierced more than fifty years ago during the sinking of two coal pits, Drumpark and another, probably Bargeddie, both of which have been long since abandoned. It is not known that it has been recorded in any subsequent borings or sinkings in the district, but, as the band is thin and not very rich in fossils, it would probably escape the notice of any but an enthusiastic observer. It may possibly be lenticular and die out altogether in places.

In the Drumpark Pit, according to Mr. Skipsey,[2] the band occurs 53 fms. above the Upper Coal, and consists of a purplish red blaes, a foot or a foot and a half thick, which contains reddish nodules containing 23 per cent. of peroxide of iron. The marine fossils are found chiefly in these nodules, and to a less extent in the surrounding blase. The list of the fossils observed may be rendered as follows, according to the present system of nomenclature :—

Crinoid ossicles.
Orbiculoidea nitida (*Phill.*) [Discina *Auctt.*]
Productus scabriculus (*Martin*)
Protoschizodus axiniformis (*Portl.*)
Conularia quadrisulcata (*J. Sow.*)
Euphemus urei (*Flem.*) [Bellerophon *Auctt.*]

It should be stated that in the North Calder section near Palacecraig, three miles east of Drumpark, and considerably outside the limits of the map, we again find a marine band which is about 53 fms. above the Upper Coal. This band, however, differs lithologically from that described by Skipsey, and is chiefly represented by a dark grey ferruginous limestone about 6 in. thick.[3] It is worthy of note also that the marine beds in other coalfields of Scotland, which seem to correspond in position to Skipsey's Band, have a close lithological resemblance to the Palacecraig exposure (*see* p. 94)

W. B. W., C. T. C., M. M.

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[1] *See* p. 94.

[2] 'On the discovery of Carboniferous Limestone Fossils in the Upper Coal Measures to the East of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. ii., part i., 1865, p. 52.

'On the Range and Occurrence of Anthracosia and other shells in the Coal Measures Eastward of Glasgow, *ibid.*, part ii., 1866, p. 141.

[3] *See* ' Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, pp. 69-70; 2nd edition, 1925, p. 86.

CHAPTER VII.

PALÆONTOLOGY OF THE CARBONIFEROUS ROCKS OF THE GLASGOW DISTRICT.

The study of the organic remains from the Carboniferous rocks of this area deserves the close attention of palæontologists, as in this respect this ground has been a classical one since the earliest days of geological research.

Although there are but few natural exposures of fossiliferous beds, those that are available have yielded during the last hundred years a rich harvest of fossils, many of which have stood as the types of species subsequently found in various parts of the world. Thus, many of the familiar names that appear in the lists of fossils from the Carboniferous rocks of Britain and the Continent, are those of fossils from the neighbourhood of Rutherglen and East Kilbride, described for the first time by David Ure, over a hundred years ago. Ever since Ure's pioneer work the interest in palæontological research has been the dominant feature of the enthusiastic studies carried on by Glasgow geologists, and the results achieved have more than a merely local importance, as testified by the numerous references, in British and foreign text-books, to various palæontological papers published in Glasgow.

The science of palæontology has two distinct aspects : faunistic and morphological ; in the first case an attempt is made to establish the nature and distribution of the life of former times, whilst in the second case the structure of the fossils is studied from the point of view of their mutual relations. The district under revision lends itself especially well to these two kinds of research : we have now a very complete knowledge of the Carboniferous fauna and flora of the Glasgow area, whilst from time to time valuable additions have been made to our knowledge of the detailed structure of various groups of fossils. That the district is rich in species is shown by the very elaborate lists published by the Local Committee for the Meetings of the British Association for the Advancement of Science, in 1876 and 1901, and all specialists are aware of the very perfect state of preservation of the fossils obtained from the limestone shales. Bivalves showing important internal characters have been figured, and the Bryozoa from the Hairmyres shales stand to this day unrivalled as regards perfect preservation ; the types and figured specimens in the Museums and private collections of the city of Glasgow are therefore very numerous and of the highest value to the specialist.

Fossils are very unequally distributed throughout the Carboniferous rocks. Around Glasgow the lowest division or Calciferous Sandstone Series is not so fully developed as in Fife, and is comparatively barren, that is, the conditions of deposition were such that in its lower half or Cementstone group, marine beds are apparently not represented, so that the only fossils that have so far been obtained from this division are obscure plant and fish remains, and Ostracods.

Higher up, marine and estuarine conditions were often favourable to life, so that it is in the upper portion of the Calciferous Sandstone and in the Carboniferous Limestone Series that fossils occur in the greatest abundance and in the greatest variety of species.

As might be expected from the coarser nature of its sediments, the Millstone Grit is not rich in fossils ; marine forms have been found only near its base, whilst the higher portions are barren but for a few drifted plant remains.

The Coal Measures contain fossiliferous bands of fresh-water or estuarine origin ; the organisms found there are often gregarious, so that although the number of specimens may be great the number of species is restricted. Marine beds are seldom met with. On the other hand it is in this series that plants are most abundantly developed.

A short account will now be given of the distribution of the fauna and flora of the subdivisions of the Carboniferous rocks, beginning with the lowest or Calciferous Sandstone Series.

CALCIFEROUS SANDSTONE SERIES.

The basal portion, or Cementstone group, is composed of sediments the nature of which indicates peculiar conditions of deposition unfavourable to the development of animal life. It may be that these strata were deposited in shallow lagoons to which the open sea had restricted ingress, since no undoubted marine organisms have as yet been detected in them ; besides, the " cement " bands appear to have had an inorganic origin. The fossils so far known from this group are poorly represented : plant-remains occur at the Corrie of Balglass and at the Spout of Ballagan, and the latter locality has yielded a suite of Entomostraca characterized by a very thin shell, thus pointing to non-marine conditions. Of the higher organisms, fish scales have been found in Auchenreoch Glen, near Dumbarton.[1] Although so few fossils have been obtained from this horizon, it is possible that a band, hitherto unnoticed, may some day prove to be more fossiliferous, and on account of the stratigraphical position of these beds, such a discovery should prove of considerable interest.

The upper part of the Calciferous Sandstone Series is exposed at a few localities which have yielded an interesting suite of fossils.

Flora.—Few plants have been obtained from these beds. In the British Association Handbook for 1901, Dr. Kidston gives a list of five species, all the localities being outside the sheet ; since then Mr. Tait has found a bed containing plants in a railway cutting about one and a half miles S.E. of Paisley, near Tillysow. Dr. Kidston identified these plants as—

Adiantites (?)
Lepidodendron sp.
Rhodea moravica (*Ett.*)
Sphenopteridium pachyrrhachis (*Göpp.*)
Sphenopteridium sp.
Sphenopteris sp.
Small seed indetermined [Carpolithus].

In his table of the distribution of Carboniferous plants,[2] Dr. Kidston shows that *Sphenopteridium pachyrrhachis* (Göpp.) is a species confined to the Calciferous Sandstone Series: its presence here conforms with the stratigraphical evidence, the bed from which it was obtained being known to occupy a position a short distance above the Dykebar Limestone (p. 22).

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[1] *See* J. Young, 'The Geology of the Campsie District,' *Trans. Geol. Soc. Glasg.*, vol. i., part i., 1860, p. 17 ; third ed., 1893-4, p. 30.

[2] *Proc. Roy. Phys. Soc. Edin.*, vol. xii., 1894, p. 240.

To the above list may be added *Lepidodendron veltheimianum* Sternb. and *Lepidostrobus* sp., obtained at about the same horizon in a stream section near Tillysow, in the north angle of the two roads about one and a half miles S.E. of Paisley.

Fauna.—Marine beds abundantly fossiliferous occur at various horizons in the upper part of the Calciferous Sandstone Series. The marine conditions which recurred from time to time during the deposition of the Carboniferous Limestone Series, had begun long before the time at which the Hurlet Limestone was deposited. Similarity of conditions induced a similarity in the nature of the fauna, so that many species found in this upper portion of the Calciferous Sandstone Series still exist in the Carboniferous Limestone proper.

Within the area of the Glasgow Sheet one of the lowest marine beds so far known is the Hollybush Limestone (p. 21), blocks of which were found among the materials removed from the present site of the Hawkhead Reservoir, about two miles S.E. of Paisley. The fossils collected by Mr. Tait are—

Cyclophyllum *aff.* wünschi (*Thom.*)
Diphyphyllum sp.
Lithostrotion junceum (*Flem.*)
Spirifer *cf.* bisulcatus *J. Sow.*
    ,, trigonalis (*Mart.*)
    ,, *cf.* striatus (*Mart.*)
Athyrid
Rhipidomella michelini (*L'Eveillé*)
Orthotetid
Productus latissimus *J. Sow.*
    ,, longispinus *J. Sow.*
    ,, punctatus (*Mart.*)
    ,, of semireticulatus group
    ,, martini *J. Sow.*
    ,, sp.
Pectiniform shell.

Here the fossils belong to the common species usually met with higher up in the Carboniferous Limestone Series. It is interesting to record the presence of *Productus latissimus* in these strata, since this species was for a long time supposed to be essentially a Carboniferous Limestone one, attaining its chief development in the Index Limestone.

In blocks of limestone from an old quarry at Hollybush, now closed, Mr. Macconochie found—

Spirifer *cf.* crassus *de Kon.*
Composita ambigua (*J. Sow.*)
Athyrid
Productus giganteus (*Mart.*)
    ,, scabriculus (*Mart.*)
    ,, pugilis *Phill.*

and from the blaes above the limestone position

Archæocidaris spine
Rhynchonellid
Pectiniform shell
Orthoceras sp.

As in neither case could an exhaustive search be made, on acount of the lack of a good exposure, these lists cannot pretend to be wholly representative of the fauna of the Hollybush Limestone, but the important point is that all the species found here, also occur higher up in the Carboniferous Limestone proper. There is thus, so far as invertebrate life is concerned, no palæontological break between the upper part of the Calciferous Sandstone Series and the Carboniferous Limestone; this obtains not only within the area of the Glasgow Sheet, but also in other districts where marine phases occur in the upper portion of the Calciferous Sandstone Series, as, for instance, in Western Fife (*see* p. 14).

CARBONIFEROUS LIMESTONE SERIES.

Flora.—A list of the plants obtained from this series is given by Dr. Kidston in the British Association Handbook for 1901. Most of the Lower Carboniferous genera are represented, and the list is quite illustrative of the results achieved by Dr. Kidston in his work on the British Carboniferous Flora.[1]

One of the prevailing plants is *Lepidodendron veltheimianum* Sternb., remarkable examples of which are preserved in the "fossil grove" at Victoria Park, Whiteinch,[2] in strata belonging to the upper part of the Lower Limestone Group or to the lower part of the Limestone Coal Group. From the same series, at Robroyston, was obtained the rare *Sigillaria youngiana* Kidston, a species remarkable in being one of the only two ribbed Sigillariæ met with in British Lower Carboniferous rocks. The root known as *Stigmaria ficoides* is common throughout the series, whilst a number of ferns were found at New Braidbar Quarry, immediately under the Orchard Limestone, but, generally speaking, the plants collected from the Carboniferous Limestone strata of the Glasgow area are not so abundant as in the east of Scotland, this apparent paucity being perhaps partly due to the fact that sinking operations through these strata have been reduced of late years.

Fauna.—The area offers typical examples of the different conditions under which the sediments were deposited, and as the conditions which affected the nature of the sediments also affected the distribution of animal life, the fauna contains representatives of open sea, shore, and brackish water animals, whilst organic remains to which a fresh-water habitat is generally attributed, are also represented. The palæontologist has thus within a restricted area the means of making himself practically acquainted with types of fossils which are to be found, more or less modified, all the world over, and has thus a better chance of thoroughly grasping all the facts regarding Lower Carboniferous life, than if our Carboniferous Limestone Series were represented by one solid mass of limestone. On account of this diversity, it will be convenient to give a short sketch of the various groups, so as to show how their occurrence is often linked with their habitat.

Foraminifera.—These organisms, which seldom fail to be present in all parts of the world where marine formations are known, are well represented in the West of Scotland; a long list, based on the works of H. B. Brady and J. Young, is given in the British Association Handbook,[3] but of these only a few were actually found within the area of this Sheet. Unless the limestones and calcareous shales in which the Foraminifera occur are weathered, the latter are not easily seen, thin sections being necessary to show their presence, so that a good many may have escaped observation. Until large collections are made, it will therefore not be possible to assert that any of these organisms are confined to a definite horizon.

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[1] Summarised in *Proc. Roy. Phys. Soc. Edin*, vol. xii., 1894, p. 224.

[2] *See* p. 163. Also R. Kidston, 'Note on the Nature of the Fossil Trees found at Whiteinch,' *Trans. Geol. Soc. Glasg.*, vol. viii., 1888, p. 235.

[3] 1901, p. 477. *See also Trans. Geol. Soc. Glasg.*, vol. ix., part ii., 1893, p. 313.

Spongiæ.—The sponge remains, discovered in 1876 by Mr. J. Smith, occur in both the Lower and Upper Limestone groups, but have so far been recorded from localities outside the sheet. Mr. Smith has made the observation[1] that they are found most abundantly in the upper division, and generally in limestone beds.

Anthozoa.—Locally, corals are very abundant, as testified by the long lists of species described by the late James Thomson.[2] They will some day prove of the greatest value in the zoning of the Scottish Carboniferous rocks, but as the group is at the present time being revised according to modern methods, further considerations must be deferred till this revision is completed, especially in view of the numerous changes in nomenclature that will have to be introduced.

Echinodermata.—In the West of Scotland Echinodermata are represented by but few species, although the remains of some forms of crinoids are often so abundant as to form thick beds of limestone. For instance, the Hurlet Limestone, in its typical development, is essentially composed of crinoidal remains. Even the relatively rare *Archæocidaris* could be sometimes gregarious to the extent of forming layers of considerable thickness; Young and Armstrong record the occurrence, at Campsie, of a calcareous band 2 to 3 in. in thickness, made up of the remains of this sea-urchin.[3]

The stratigraphical distribution of the Carboniferous crinoids in Scotland as a whole will be dealt with in a forthcoming paper by Mr. James Wright of Kirkcaldy.

Annelida.—These are represented by both marine and brackish, and possibly fresh-water, species. Although isolated specimens are often met with, clusters in quantities sufficient to make up bands of limestone—"*Spirorbis* limestone"—are not known in the Glasgow area.

Bryozoa.—The Carboniferous Bryozoa of this district are among the most numerous and best preserved in Britain, and have been the subject of valuable studies, the foremost of which are those of the late John Young and of the late R. Etheridge. To these authors are due the descriptions of many species discovered in this area, together with observations of high interest bearing on questions of morphology or of ontogenic development.[4]

The determination of the Fenestellids is often difficult from the fact that the cellular or "obverse" side of the colony is usually firmly embedded in the matrix, but to John Young we owe the discovery of a process by means of which this side can be exposed when the matrix is not too hard.[5] Of special interest are his researches on the development of *Fistulipora incrustans* (Phill.); he showed that this organism passes through a "*Ceramopora*" stage and a "*Thecostegites*" stage before forming a typical *Fistulipora*, and made the further important observation that in certain localities only one stage may occur, whilst the three may be found together elsewhere.[1]

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[1] *British Association Handbook*, 1901, p. 479.

[2] 'On the Development and Generic Relation of the Corals of the Carboniferous System of Scotland, *Proc. Phil. Soc. Glasg.*, vol. xiv., 1883, pp. 296-520.

[3] *Trans. Geol. Soc. Glasg.*, vol. iii., 1871, p. 20 of Appendix.

[4] Numerous papers by Dr. John Young are to be found in the *Transactions of the Geological Society of Glasgow*, in the *Proceedings of the Natural History Society of Glasgow*, and in the *Annals and Magazine of Natural History*, from 1874 onwards.

[5] *Proceedings of the Natural History Society of Glasgow*, vol. iii., 1877, p. 207.

The Lower Carboniferous Bryozoa seem to have been very sensitive to changes of conditions, so that their range in time in the Glasgow district cannot be accurately determined; but, generally speaking, conditions suitable to their development were more prevalent in Lower Limestone than in Upper Limestone times.

Brachiopoda.—Our knowledge of the West of Scotland Brachiopoda rests mainly on Davidson's monograph, in which contributions by local workers are embodied. In the British Association Handbook for 1901, Mr. J. Neilson summarizes the observations contained in this great work, and his most interesting conclusions are based on evidence to be found within the area of the Glasgow Sheet. Not only are the species numerous, but the individual number of specimens is also very great, so that the Brachiopoda are the most conspicuous marine fossils in the district.

There is now, both in Britain and abroad, a tendency towards drawing finer specific distinctions, and the modern school palæontologists are of opinion that the Brachiopoda have hitherto been given too great specific latitude. It is therefore probable that the number of species known at the present time from the Glasgow area, will be increased when the new methods are applied to the material collected. However, even allowing for this contingency, inspection of the lists shows that Brachiopoda are more abundantly distributed in the Lower than in the Upper Limestone Group; while in the Limestone Coal Group they appear—with the exception of *Lingula*, an organism which can stand a large admixture of fresh-water—to be confined to two horizons, the Johnstone Shell-bed and the marine band in the Black Metals.

At the time of writing it is not possible to assert that any forms are absolutely confined to the one or the other of the Lower and Upper Limestone Groups. But, possibly on account of the fact that the physical conditions necessary to the development of certain groups of species were fairly constant over relatively wide areas, there are certain assemblages which appear to be more characteristic of one horizon. For instance, *Productus giganteus* (Mart.) in its typical development as a transverse form longitudinally furrowed, *Productus spinulosus* J. Sow., *Pr. aculeatus* (Mart.), *Pr. fimbriatus* J. Sow., and *Pr. pustulosus* Phill., appear to be restricted to Lower Limestone horizons. *Pr. latissimus* J. Sow., *Pr. costatus* J. de C. Sow., *Pr. sinuatus* de Kon., *Pr. scabriculus* (Mart.), and *Pr. longispinus* J. Sow., are common to both series, but are more abundant in the Upper Limestone Group. Among the Strophomenids, *Schellwienella crenistria* seems to be the prevalent form in the Lower Limestone Group, whilst representatives of the genus *Derbya* are recognised in the Upper Limestones. Of the Athyrids, *Composita ambigua* (J. Sow.) is common to both series, whilst *Athyris planosulcata* Phill. and other Athyrids have been recorded from Lower Limestone localities only. The Spiriferids will require to be studied in detail before their vertical distribution can be made clear, but it may be mentioned here that the Upper Limestone Group has yielded a form externally remarkably like *Spirifer mosquensis* (Fischer de Waldheim). Of the Orthids, *Rhipidomella*

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[1] *Trans. Geol. Soc. Glasg*, vol. vii., 1885, p. 244.

michelini (L'Eveillé) is in this area a Lower Limestone form, whilst the small form usually referred to *Schizophoria resupinata* (Mart.) is common to both groups, but this name includes probably more than one variants or mutations. As regards the Terebratuloids, conditions seem to have favoured their development in Lower Limestone times far more than during the deposition of the Upper Limestone Group. The Rhynchonellids are also more abundantly represented in the Lower Limestone Group.

Although physical conditions probably played a leading part in governing the vertical distribution of the Brachiopods in this area, the typical assemblages as above sketched are nevertheless of high interest and often of great economic importance, as, within short distances at least, they may help to correlate one bed with another, and since they are the most widespread marine organisms in the district, this fact should not be overlooked.

Lamellibranchiata.—Dr. Wheelton Hind has described [1] 340 species of lamellibranchs from the Carboniferous rocks of the British Isles, 144 of which occur in the West of Scotland, 125 being Lower Carboniferous forms. Of the latter, the greater part are represented in the area under revision, and Dr. Hind's results have been based largely on the collections of the Glasgow geologists, especially that of Mr. J. Neilson. The localities from which these numerous species were obtained are indicated in Dr. Hind's monographs, and in the British Association Handbook for 1901.

A glance at the lists shows that a few species appear to be confined to the Upper Limestone Group, and a large number to the Lower Limestones, whilst a good many forms are common to both series. Dr. Hind has shown, in the general table of distribution at the end of his monograph, that though some species are confined to the Calciferous Sandstone Series, some to the Carboniferous Limestone and others to the Upper Carboniferous, none appear to characterize any definite horizon within the Carboniferous Limestone proper. This remark need not necessarily apply to this region, since part of the Carboniferous Limestone of Scotland is homotaxially higher up in the sequence than the Carboniferous Limestone of England; it may thus be possible that some of the species which in the Glasgow area do not pass upwards into the Upper Limestone Group, had really died out at the close of Lower Limestone times.

Special mention must be made of the curious species *Edmondia punctatella* (Jones) which was for a long time held to be a crustacean belonging to the genus *Estheria*. It occurs in vast numbers in numerous localities, and, strangely enough, always at the same horizon, in an alum-shale almost immediately underlying the Calmy Limestone. A temporary exposure of this bed near Thornliebank has been described by Mr. J. Neilson;[2] the bed has since been traced in the Waulkmill Glen and at the mouth of the Darnley fireclay mine where it is still to be seen, and a description of these two outcrops has been given by Prof. P. Macnair.[3] In the north-east part of the area the *Punctatella* bed was found by Mr. Tait at Chryston; in the Caledonian (now L.M.S.) Railway cutting three-quarters of a mile west of Hogganfield Loch; in a stream half a mile north-east of Milton of Campsie; and in a number of deep borings. The constant occurrence of this bed at the same horizon points to special conditions, but as these occurred apparently once only during the deposition of the Carboniferous Limestone of Central Scotland, *Edmondia punctatella* is, in this area at least, a good index of the position of the Calmy Limestone.[1]

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[1] *Palæontographical Society's Monographs*, 1894-1905.

[2] *Trans. Geol. Soc. Glasg.*, vol. xii., part iii., 1906, p. 294.

[3] *Ibid.*, p. 383.

Another lamellibranch forming actual beds is *Naiadites crassa* (Flem.). Although not confined to a definite horizon, it flourished during Lower Limestone times; a thin bed made up of its remains is exposed in the Corrie Burn section, some 9 ft. below the Coral Limestone. *Posidonomya corrugata* again is particularly abundant close to the Top Hosie.

Gasteropoda.—A large number of species are recorded from the Carboniferous Limestone Series of the Glasgow area, but the group not having been entirely revised according to modern methods, the question as to whether their vertical distribution obeys any definite law, must remain an open one. As in the case of the cephalopods, their favourite habitat was a muddy water, so that they are usually found most plentifully in fine muddy shale, and often in excellent preservation. Seldom do they occur in limestone, an exception being found in the "Bellerophon Limestone" which is exposed in the burn above Shields cottage, one mile north of Milton of Campsie, and also in the Corrie district (*see* pp. 44, 46).

Cephalopoda.—Compared with the East of Scotland, the western district is much richer in species as well as in individuals of cephalopods. In the British Association Handbook for 1901, Mr. J. Neilson gives a list of 49 species, most of which were found within the area. According to this list, they include a large proportion of the more common forms, as developed in the typical districts of England, the Goniatites alone being represented by no less than fifteen species, a very large number for any Carboniferous area. But as the Carboniferous cephalopods of this region have not been the object of special study, details as to their vertical distribution cannot be given.

Like most of the gasteropods and some of the mud-dwelling lamellibranchs, they are more often found in soft shaly beds than in solid limestone, a fact which explains the remarkably good preservation of many of the Goniatites and Nautiloids, which can thus easily be freed from their matrix so as to expose the suture-line and other characters.

Crustacea.—Of the Crustacea, the more geologically important in the district are the ostracods, our knowledge of these minute organisms being embodied in the Monograph of the British Carboniferous Ostracoda by Jones and Kirkby,[2] whilst their conclusions regarding the nature and distribution of the West of Scotland species have been ably summarized in a paper by John Young,[3] who has carried out a good deal of research work in this group.

The majority of the species are marine, occurring in company with other typically marine fossils, but there are also certain species considered to be of fresh-water habitat, since they have never been found mingling with marine fossils, as for instance the genus *Carbonia* and a few species belonging to the genera *Leperditia* and *Beyrichia*. It is interesting to note that the fresh-water forms are those that show the greatest tendency to be gregarious, to the extent of forming actual beds of "Entomostracan Limestone." Typical examples are the

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[1] It is now known to occur at this horizon over a large part of the Central Coalfield as well as in Ayrshire and West Fife.

[2] *Palæontographical Society*, 1874-1884.

[3] *Trans. Geol. Soc. Glasg.*, vol. ix., part ii., 1893, p. 301.

Entomostracan (Baldernock) Limestone which usually lies at the base of the Hurlet Seam in the Glasgow area, and the Hosie (Blackhall) Limestone of the Campsie district, described by John Young.[1] Ostracods, marine and fresh-water, were as a whole more abundant in the Lower Limestones than in the Upper Limestones. This is doubtless on account of difference in physical conditions, to which they seem to have been very sensitive, as shown by the fact that certain species appear to be restricted to limited areas.

Trilobites, as is usually the case in Carboniferous rocks, are nowhere abundant, and are restricted to a very few species.

Interesting remains of the higher crustacean genera *Palæmysis* and *Crangopsis* were obtained by the late Andrew Patton from the cementstone quarry of East Kilbride, and have been described in detail by Dr. B. N. Peach.[2]

This rich locality also yielded an air-breather belonging to a new genus of myriapods, which Dr. Peach named *Pattonia*, after its discoverer.[3] The south part of the area is also one of the richest in species of *Dithyrocaris*; these have been fully described by Messrs. R. Jones and H. Woodward.[4]

Pisces.—The most recent summary of the Carboniferous ichthyology of Western Scotland is incorporated in the British Association Handbook for 1901, and is the work of Dr. R. H. Traquair, who based his study on the examination of all the public and private collections of Glasgow and the West of Scotland. His lists clearly show that in this region the fauna consists mainly of Elasmobranch forms, and he observes that a large proportion of the species are marine—a marked difference from what obtains in the East of Scotland, where at this horizon the species are mostly estuarine. An interesting point, mentioned in one of his memoirs,[5] is the rare occurrence of a commingling of the marine and estuarine faunas, a notable instance of which is found in the shales that overlie the Calderwood cement at East Kilbride, where estuarine forms such as *Rhizodus hibberti* (Ag.) and *Elonichthys robisoni* (Hib.) occur together with such typically marine species as *Petalodus acuminatus* (Ag.) and *Psephodus magnus* (M'Coy), etc. Dr. Traquair also refers to the zonal question, with the remark that he is not aware that any definite succession of forms can be established in the fish fauna of the marine limestones.

MILLSTONE GRIT.

There are but few sections exposing fossiliferous beds of Millstone Grit age in this area. The Garngad Road section, near the base of the series, is described on pp. 83-84, and its fossiliferous character was first made known in 1875 by Mr. J. Neilson,[6] who gives a comprehensive list of the fossils he collected.

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[1] *Ibid.*, vol. x., part ii., 1896, p. 334.

[2] 'The Higher Crustacea of the Carboniferous Rocks of Scotland,' *Mem. Geol. Surv.*, 1908.

[3] *Proc. Roy. Phys. Soc. Edin.*, vol. xiv., 1902, p. 114.

[4] *Palæontographical Society's* 'Monograph of the British Palæozoic Phyllopoda,' 1898.

[5] 'On the Distribution of Fossil Fish-remains in the Carboniferous rocks of the Edinburgh District,' *Trans. Roy. Soc. Edin.*, vol. xl., 1905 (issued separately, 1903), p. 698.

[6] 'Geological Notes on the Cuttings in the City of Glasgow Union Railway, etc.,' *Trans. Geol. Soc. Glasg.*, vol. v., 1877, p. 222.

The *Plants* from this locality, collected by Mr. Tait and submitted to the late Dr. R. Kidston, have all Lower Carboniferous affinities. It may be mentioned here that the result of careful search, outside this area, led Dr. Kidston to the conclusion that the lower third of the Millstone Grit is, so far as plant life is concerned, to be considered as of Lower Carboniferous age.[1] The *Fauna* consists essentially of brachiopods and molluscs, with rare remains of Crustacea and fishes.

The lamellibranchs and gasteropods of the Millstone Grit of Scotland have been the subject of an exhaustive monograph by Dr. Wheelton Hind,[2] who has brought to light the important fact that a large proportion of the forms were new to Britain, but at the same time identical with well-known American species. Many of these species common to America and Scotland have also been recorded from Russia, and it is interesting to note that both in that country and in America they occur in beds belonging to a late period of Carboniferous times.[3] As the brachiopods also appear to have Upper Carboniferous affinities, it seems probable that shortly after the close of the Carboniferous Limestone Series, the marine invertebrate fauna underwent a sudden change, but no explanation can be given at the present time of the nature of the process through which this change was evolved. Since the beds in which these fossils occur in this region are probably homotaxially lower down the sequence than the Upper Carboniferous beds in which they occur in Russia and America, their presence here is not likely to be the result of migration, and it may be safer to assume that they mark a sudden expansion of forms pre-existing in Carboniferous Limestone strata, though not yet detected in them.

The conditions suitable to the development of these forms were of short duration, and, so far as is known, never recurred in this area: the few thin marine bands occasionally developed in the Coal Measures have not yet yielded any representatives of this curious fauna.

COAL MEASURES.

As is the case generally throughout Britain and Western Europe, the Coal Measure strata of this district were deposited principally in brackish and fresh waters, the coal seams possibly representing partly submerged forests, or swamps somewhat of the nature of the recent mangrove swamps of America. Hence plants are the more prominent and varied fossils, the fauna being restricted to a few but characteristic species.

Flora.—In the British Association Handbook for 1901 (pp. 468-476) Dr. Kidston gives a complete list of the Coal Measure plants found in Western Scotland. Many of these are not recorded from the Glasgow area, probably owing to the fact that comparatively few pits have been sunk of late years in this district. However, those plants which from their abundance and general distribution are regarded by Dr. Kidston as characteristic of the Series, are represented: *Neuropteris heterophylla* Brongt., *Alethopteris lonchitica* (Schloth.), *Sphenopteris obtusiloba* Brongt., *Lepidodendron ophiurus* Brongt., *Calamites suckowi* Brongt., etc. It may be mentioned here that the Productive Coal

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[1] *See* page 10 and references given there.

[2] *Trans. Roy. Soc. Edin.*, vol. xlvi., 1909, p. 331 (issued separately 1908).

[3] *Cf.* p 88.

Measures of this area, as defined by their flora, belong mainly to the Lower Coal Measures, for which Dr. Kidston has proposed the term "Lanarkian Series."[1]

In other districts this lower series[2] is overlaid by a Middle Coal Measure Series or "Westphalian Series" characterized by a flora peculiar to itself. Dr. Kidston has drawn attention to the fact that the lower series is distinguished from the middle one not so much by a flora peculiar to itself, as by the absence of many of the species typical of the later series.[3] It is therefore important that the beds above the Productive Coal Measures of the district should be searched for any indications of these characteristic plants.

Fauna.—As stated above, the Coal Measure fauna is essentially a brackish-water one, with occasional recurrences of marine groups. Remains of terrestrial organisms are represented by fragments of scorpion skin, common enough in coal seams.

The brackish-water fauna consists mainly of lamellibranchs belonging to the genera *Naiadites*, *Carbonicola*, and *Anthracomya* ; the first belongs probably to the Mytilidæ and the others to the Unionidæ. A characteristic feature of these organisms is their gregariousness, leading to the formation of the "musselbands" of miners. The frequent occurrence of these shells forced itself on the attention of palæontologists, and attempts have been made to find whether certain forms are confined to definite horizons. The earliest publication bearing on this subject locally is that of R. W. Skipsey, "On the Range and Occurrence of *Anthracosia* and other Shells in the Coal Measures Eastward of Glasgow,"[4] in which he gives an excellent account of the distribution of the principal species in that area. A complete summary of the main data bearing on the vertical distribution of these fossils in Lanarkshire and the West of Scotland is embodied in a tabular form at the end of Dr. Hind's monograph on "*Carbonicola*, *Anthracomya* and *Naiadites*."[5]

From this and Survey material determined by Dr. Hind it appears that none of these forms can be said to be restricted to a definite horizon, although, locally, conditions were sometimes specially favourable to the development of one species to the exclusion of others, as for instance the species of *Carbonicola* which makes up the "Cambuslang marble." On the other hand, if these conditions obtain uniformly over a wide area, an exact knowledge of the vertical distribution of typical species can be of great importance to the mining engineer. Thus, in the Coal Measures of North Staffordshire the distribution of several species of *Anthracomya*, *Carbonicola* and *Naiadites* is so constant that Dr. Hind has been able to draw up a Fossil Chart of the North Staffordshire Coal-field for the practical use of mining engineers in mining operations.[6] The Annelid *Spirorbis*, which in certain districts forms persistent bands of "Spirorbis Limestone," is met with here mainly as isolated specimens attached to shells or plants.

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[1] 'On the Divisions and Correlation of the Upper Portion of the Coal Measures, with special reference to their development in the Midland Counties of England,' *Quart. Journ. Geol. Soc.*, vol. lxi., 1905, p. 319.

[2] The division between the two Series may be drawn approximately at the Ell Coal. *See* 'Economic Geology of the Central Coalfield,' Area V., *Mem. Geol. Surv.*, 1916, p. 126; 2nd edition, 1925, p. 145.

[3] *Proc. Roy. Phys. Soc. Edin.*, vol. xii., 1894, p. 226.

[4] *Trans. Geol. Soc. Glasg.*, vol. ii., part ii., 1866, pp. 141-144.

[5] *Palæontographical Society*, 1894.

[6] Published in 1903 by the North Staffordshire Institute of Mining and Mechanical Engineers.

Dr. R. H. Traquair has determined from the West of Scotland forty species of Upper Carboniferous fishes belonging to twenty-six genera. A list of these is given in the British Association Handbook for 1901 and in his memoir on the Carboniferous fishes of the Edinburgh district (*loc. cit.*). In these works Dr. Traquair makes some remarks of general importance which may be summarized here, as they also apply to the Glasgow district.

The Upper Carboniferous fish fauna of the West of Scotland is essentially estuarine, whilst that of Lower Carboniferous age is principally marine. The difference between the two faunas is very striking, since two species only have so far been found to be common to both series. The Upper Carboniferous fish fauna of the West of Scotland is the same as that which occurs at the same horizons in the rest of Britain, most of the characteristic forms being present. An interesting point is that the Upper Carboniferous estuarine fish fauna is, in the main, the same in the Lower as in the Middle division of the Coal Measures, so that ichthyological life-zones cannot be established in these strata.

The Airdrie and Quarter districts have yielded remains—skulls and jaws—of amphibians belonging to the order Stegocephalia, the better characterized being *Anthracosaurus russelli* Hux.[1] and *Loxomma allmani* Hux.[2] In other districts these amphibians are also known from Lower Carboniferous strata.

Marine beds.—Marine fossils from the Coal Measures of the Glasgow district are not abundant, but their occurrence is important from an economic as well as from a theoretical point of view.

The lowest bed recorded was discovered in 1897 by Mr. J. Neilson[3] in temporary excavations at Alexandra Parade, Glasgow. The fossils found belong to *Lingula*, *Murchisonia*, *Loxonema* and to a small form of Goniatite. The position of this bed is stated to be near the base of the Coal Measures. Higher up in the sequence, at Calderbank near Airdrie, Mr. R. Dunlop obtained from a bed lying between the Kiltongue and Virtuewell Coals, marine fossils which he refers to *Pterinopecten papyraceus* (J. Sow.), *Orthoceras* sp., and a species of Goniatite.[4]

The highest bed in the series is that discovered long ago by R. Skipsey, near Drumpark, Coatbridge.[5] It has since been traced by various observers over a wide area in Scotland, and a full account of its nature and extension is embodied in a paper by Messrs. J. Smith and C. T. Clough.[6] The fauna found at this horizon consists of brachiopods, lamellibranchs, gasteropods, cephalopods, etc., most of which are apparently closely related to Lower Carboniferous forms, but it is possible that further study, based upon more abundant material, may prove some of them to be well-defined mutations of the Lower Carboniferous species to which they have been referred. In the meantime, the species collected do not seem to contain any representatives of a fauna analogous in character to that discovered at the base of the Millstone Grit, that is, having a facies suggesting affinities of Russian or American Upper Carboniferous type. Since this band appears to keep a definite horizon, it may prove of economic importance as an index, when boring in unproved or little known areas (*cf.* pp. 93-94.)

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[1] From the Airdrie Blackband Ironstone at Chapelhall and Quarter; *see* T. H. Huxley, 'Description of *Anthracosaurus Russelli*,' *Quart. Journ. Geol. Soc.*, vol. xix., 1863, p. 56. The Quarter referred to lies a little south of Hamilton.

[2] From the Palacecraig Ironstone, Carnbroe.

[3] *Trans. Geol. Soc. Glasg.*, vol. xi., part i., 1898, pp. 147, 149.

[4] *Ibid.*, vol. viii., 1888, p. 342, and vol. xiii., part i., 1907, p. 35. Nowhere else have marine forms been obtained at this horizon, though carefully looked for in the immediate neighbourhood of Mr. Dunlop's locality. *See* 'Economic Geology of the Central Coalfield,' Area V., 2nd edition, 1925, p. 64. Perhaps Mr. Dunlop's specimens came from a boulder of Skipsey's Marine Band, an exposure of which occurs in the North Calder 1½ miles to the west.—M. MACGREGOR.

[5] *Ibid.*, vol. ii., part i., 1865, p. 52.

[6] Summary of Progress for 1907, *Mem. Geol. Surv.*, 1908, p. 127.

The Red Beds overlying the Productive Coal Measures have not yet yielded fossils showing to what extent they may belong to the Middle and Upper divisions of the Coal Measures, as obtains in England, Dumfriesshire, and Ayrshire. It is to be hoped that some day well preserved fossils will be brought to light and help towards a solution of this problem.

Conditions of Deposition of the Carboniferous rocks.—The various palæontological works dealing with the Carboniferous fauna of this area show that certain abundantly represented species disappear more or less suddenly, and then reappear at a higher horizon, or, in other cases, vanish altogether so far as this region is concerned.

The apparent localisation of a form in one particular bed gave rise to the old notion that certain species were absolutely characteristic of a definite horizon; but although true of graptolites and Mesozoic cephalopods, this is not the case as regards invertebrate life in Carboniferous times. Before trustworthy "life-zones" can be established in these rocks, we must have a thorough knowledge of the physical conditions which affected the development and the distribution of the organisms. As regards the Lower Carboniferous rocks of the Glasgow area, it may be said that they represent recurring cycles of sedimentation due to some such causes as changes in the position of the shore-line, or of the rivers and marine currents. As many organisms are extremely sensitive to changes in their environment—alteration in the nature of the water, incoming of coarse sediments, etc.—it follows that during the above-mentioned cycles certain forms would either be killed or driven away, or would undergo changes such as dwarfing, or modifications in the nature of the shell and ornamentation. Taking as an illustration the marine beds of the Lower Limestone Group in the Glasgow area, they contain a well-known assemblage of fossils which are not represented in the shales of the Limestone Coal Group. With the advent of the Upper Limestones, a similar fauna recurred, but not quite so rich, some of the Lower Limestone forms being either absent or much reduced in number. For instance, the less mobile groups such as the Bryozoa and corals have undergone a striking reduction, and play a quite restricted part when compared with those flourishing in the Lower Limestone Group, although it cannot be said that they are extinct. These facts must be taken into consideration when establishing or correlating "life-zones" on the presence or absence of certain forms; a fossil which is the "index" of a zone in England may not be found in Scotland, but it does not follow that strata of the same age as those of the English zone are absent, *i.e.*, that there is a gap. It is quite as likely that the physical conditions did not suit this organism, hence its absence at the spot. *Vice versa*, a form considered to be typical of a definite horizon in England may appear in Scotland in beds situated lower down in the sequence, if conditions suitable to its development obtained in Scotland at that time.

These relations between vertical distribution and environment have been illustrated in diagrammatic form at the end of a paper by

Messrs. Wheelton Hind and J. A. Howe ;[1] it is there shown that curves can be constructed indicating the earliest known occurrence of each species at a series of localities. These curves are named *isodietic lines*, and represent conditions of deposit, and not epochs in time.

Life-zones in the Carboniferous rocks.—The Carboniferous system, in its marine phases, has been divided into a certain number of broad zones or stages, representing periods of time defined by the occurrence of species or assemblages of species having a restricted vertical distribution. In Britain, the two lower stages constituting the Lower Carboniferous, and known respectively as *Tournaisian* and *Visean*, have been recognized. To what extent marine beds corresponding to part of the *Spirifer mosquensis* Zone of Russia may be represented in this country, is not yet determined.

These divisions represent a considerable thickness of strata, and active work is now being carried on with a view to establishing minor subdivisions indicating shorter periods. In England, the principles upon which this work is carried on are based on a scheme evolved by the late Dr. A. Vaughan, and embodied in a series of papers published by him and his co-workers in the Quarterly Journal of the Geological Society of London, from 1905 onwards.

Most fossil species, as understood by the older palæontologists, were too broadly defined to be of service in establishing narrow zones. Dr. Vaughan therefore based his work upon the study of evolutionary series in certain groups of fossils, among which he chose the corals and brachiopods on account of their abundance. A full digest of his work need not be given here, as the original sources are easily available to the reader.[2]

With regard to the position of the Carboniferous rocks of the Glasgow area as determined by their invertebrate fauna, an upper Visean age must be assigned to the fossiliferous beds in the upper part of the Calciferous Sandstone Series (Hollybush Limestone) and to the greater portion of the Carboniferous Limestone, but at the present time it is difficult to determine the upper limit of the Visean in this region, for reasons stated below.

The marine strata from the Hollybush Limestone up to the Upper Limestones contain an assemblage of species on the whole similar to the fauna which in England is characteristic of the upper sub-zone D_2 of Dr. Vaughan's *Dibunophyllum* zone. Owing, however, to certain local conditions not yet explained, this D_2 phase in Central Scotland apparently persisted during a longer period than in England. Our Upper Limestones therefore, though from stratigraphical evidence known to be higher up in the sequence than the top part of the English D_2 zone, still contain a fauna which, in our present knowledge, has D_2 affinites ; but, as already stated, is not so varied as that of the Lower Limestones. This long duration of the D_2 phase in this area does not, however, do away with the possibility of separating in it minor subdivisions of more or less local value. Important results in this direction have been achieved by Mr. R. G. Carruthers, who, by a detailed study of the members of the line of evolution of the coral *Zaphrentis delanouei* M. Ed. & H., has been able to show that in Central Scotland they can be used as "index" fossils by means of which the Lower Limestones can be differentiated from those of the upper group.[1]

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[1] 'The Geological Succession and Palæontology of the Beds between the Millstone Grit and the Limestone-Massif at Pendle Hill and their Equivalents in certain other Parts of Britain,' *Quart. Journ. Geol. Soc.*, vol. lvii., 1901, p. 380.

[2] In order to avoid lengthy periphrases Dr. Vaughan makes use of symbols. These symbols are the initial letters of the name of the fossil characterizing the zone. Thus, the Upper Visean, characterized by the coral *Dibunophyllum*, constitutes Dr. Vaughan's *Dibunophyllum* Zone, and is subdivided into subzones D_1 and D_2.

These two series can also be distinguished by means of the general assemblages of fossils they contain. With a few exceptions the distribution of these forms does not seem to have been brought on by a process of evolution : the combined list of species from both series is similar to any complete list from English D_2 localities, that is, our Lower Limestone fossils have D_2 affinities, but so have our Upper Limestone fossils. It must be understood that although these assemblages have not been proved to constitute *life-zones*, this does not detract from their importance from an economic standpoint in boring and other mining operations in the area. The Glasgow geologists have long known that certain groups of species are more characteristic of the one series than of the other, and their observations are summarized by Mr. J. Neilson in a paper in which he indicates[2] some of the species which appear to be confined to each of the two series in the West of Scotland. But a universal standard of definition will have to be agreed upon by palæontologists before it can be said that some of these forms have really died out and do not pass up into higher beds, in the marine upper divisions of the Carboniferous System outside Britain. As an illustration may be cited some of the more familiar species : *Dielasma hastatum* (J. de C. Sow.), *Rhipidomella michelini* (L'Eveillé), *Athyris planosulcata* Phill., *Productus aculeatus* (Mart.), which have been recorded from the Middle and Upper Carboniferous of Russia, but in the Glasgow area have not been obtained above the Lower Limestone Group. Their absence in the Upper Limestones is thus obviously due to migration, and it would be interesting to know whether their representatives in Russia have undergone minute evolutionary changes such as could be traced by the study of their internal characters. It is therefore difficult to locate exactly the horizons at which the species typical of the Upper Visean D_2 have actually died out. In some districts of England and Ireland Dr. Vaughan has recognized the presence of higher sub-zones which he denotes by the symbols D_3 and P, but the species characterizing these sub-zones have not yet been met with in Scotland as distinct assemblages, though marine beds of the same age are doubtless present.

An important "index" of the Visean is the group of *Productus giganteus* (Mart.) whose disappearance, according to the classification based on invertebrate life, marks the close of the lower division of the Carboniferous System. Of the species composing this group *Productus giganteus* (*sensu stricto*) is a Lower Limestone form in the West of Scotland, since, according to modern ideas, the Upper Limestone form to which this name has been given is not a true *Productus giganteus*. Another of the giganteid Producti, *Productus latissimus* J. Sow. is abundant at various horizons in the Upper Limestones, but no undoubted member of the group has yet been detected in the highest limestone of the series (Castlecary Limestone) in the districts adjoining the Glasgow Sheet. In the event of the *P. giganteus* group being proved to have actually died out at some period before the deposition of the Castlecary Limestone, the strata above that horizon would then be of post-Visean age, that is, homotaxial with the base of the *Spirifer mosquensis* zone of Russia. In support of this view we have the stratigraphical position of these beds, and their proximity to the Millstone Grit, whose invertebrate fauna has an Upper Carboniferous facies. On the other hand, it must be remembered that the boundary-line between the Lower and the Upper Carboniferous, according to the researches of Dr. Traquair and of Dr. Kidston, lies somewhat higher in the sequence.[1] The difference between the two positions of the divisional line is, however, not very great considering the widely different nature of the organisms, and it may well be that modification of the invertebrates had begun a little before the time which saw such a sudden and startling change in fish and plant life.

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[1] *Quart. Journ. Geol. Soc.*, vol. lxvi., 1910, pp. 523-538.

[2] 'History of the Glasgow Geological Society,' 1908, pp. 155-164.

At the time of writing there are no published fossil-lists from any other part of Britain, indicating the presence of a fauna analogous to that of the base of the Millstone Grit. Dr. Wheelton Hind, in his monograph referred to, has pointed out the peculiar characters of the lamellibranchs and gasteropods, and the examination of the brachiopods is likely to prove equally interesting.

It must be understood that, if in the above sketch of the vertical distribution of organisms in the Carboniferous Limestone of the Glasgow area, corals and brachiopods only are mentioned, it is to make possible a comparison with the English sequence, which is based mainly on the distribution of these two classes of fossils. G. W. L.

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[1] *Cf.* pp. 84 85.

CHAPTER VIII.

IGNEOUS ROCKS.

THE Glasgow district supplies abundant examples illustrating igneous geology, and both contemporaneous and intrusive igneous rocks are well represented. The contemporaneous products may all be assigned, broadly speaking, to a single epoch of vulcanicity, but the intrusions are undoubtedly of widely different ages ; some clearly belong to the volcanic epoch, and will accordingly be considered in connection with the superficial volcanic products in Section I. of this chapter ; others again bear an uncertain relation to the volcanic episode, or are manifestly of later and independent origin ; these will be treated in Section II.

The petrological description of the various rock types, whether contemporaneous or intrusive, is reserved for Section III., while in Section IV. an account is given of the zeolites of the Kilpatrick Hills.

I. SUPERFICIAL AND INTRUSIVE IGNEOUS ROCKS OF THE VOLCANIC EPISODE.[1]

As already stated, the volcanic rocks which enter the Glasgow map are divided into a northern and a southern outcrop with a wide interval between occupied by later subdivisions of the Carboniferous System. In addition to this, the northern outcrop is itself cut in two by the Campsie fault, which separates the lavas of the Campsie Fells to the north-east from their down-thrown continuation forming the Kilpatrick Hills to the south-west. Further, the continuity of the southern crop is broken by a shallow trough filled with conglomerate, which isolates the Cathcart Hills to the east from the main mass of the Renfrewshire lavas to the west ; the latter are represented, so far as this district is concerned, merely by a narrow strip along the extreme margin of the map.

The northern and southern outcrops are both parts of a widespread accumulation of volcanic rocks which Sir Archibald Geikie has fittingly named the Clyde Plateau. In early Carboniferous times this plateau was continuous from Arran to Stirling and from the Highland border south to Ayrshire ; for long subsequent ages it lay buried ; to-day we find it in part revealed, in part destroyed, by denudation.

Dr. Jack, Sir Archibald Geikie and other workers have recognized many vents in connection with the Clyde Plateau, several fine examples of which are included in the Glasgow district map. It is impossible therefore to regard the plateau as the product of a single central volcano. Moreover, the geographical distribution of the various types of lava building up the plateau makes it appear likely that in certain cases individual vents, or groups of vents, were more or less restricted for long periods of time to the production of certain special types of lava, in spite of the fact that neighbouring centres might have an output of quite a different character. Without some such conception as this, it is difficult to reconcile the abundance of Dalmeny basalts in the Cathkin Hills with the absence of this type in the Campsie-Kilpatrick succession. Better still, in the Campsie Fells there is a whole group of vents choked with agglomerate and intrusions of the Jedburgh type of basalt, and at the same time a specially marked development of this type of basalt among the lavas of the plateau. In some cases, however, it is clear that one and the same vent has been responsible for more than one type of eruption. The great Meikle Bin vent (Fig. 8, p. 147) in the Campsie Fells is occupied by tuffs and intrusions representing various types of basaltic and trachytic rocks.

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[1] Mr. J. V. Harrison's 'Notes on the Geology of the East Kilsyth Hills,' *Trans. Geol. Soc. Glasg.*, vol. xv., part iii., 1916, p. 315, have appeared since the first edition of this memoir. It supplies additional information regarding the Garrel and March Burns. Mr. Harrison is correct in pointing out that there is more ash in the March Burn than is indicated on the one-inch Map. Limited exposures make it impossible to draw entirely satisfactory boundaries between lava and ash at this locality.

As the several volcanic centres of the period were evidently somewhat independent of one another, it is not surprising to find that they started into activity at different times. In the Garrel Burn, volcanic rocks make a doubtful first appearance in the Upper Red Sandstone (the lowest sheets here may be intrusive), and come on in force at the base of the Carboniferous; to the west, they entirely overlie the thick Ballagan Group of shales and cementstones, in addition to the Spout of Ballagan Sandstone.

The doubtful basement lavas of the Garrel Burn district are isolated in the Old Red Sandstone, and the lower members of the succeeding volcanic pile, in the same district, interdigitate to a slight extent with Ballagan sediments. But such instances are rare. The growth of the volcanoes, once started, seems in general to have outstripped the accumulation of contemporaneous sediment; so that it is likely that the plateau, with its undulating surface swelling into domes about the active craters, stood clear of the waters and the alluvial plains of the period of its formation.[1] How, subsequently, it came to be smothered beneath a varied accumulation of volcanic debris and more normal sediment has already been described. The entire plateau was in large measure levelled down and submerged before the close of Calciferous Sandstone times. We have little evidence as to the thickness of this volcanic accumulation. Probably 2000 or 3000 ft. would not be an excessive estimate.

One last point of general interest may be referred to here. In the northern region there are numerous dykes obviously connected with the volcanic episode. The individual dykes are narrow and have never been traced far, but they belong to a group which has been followed at intervals to the Greater Cumbrae. In the latter locality dykes belonging to this group have been assigned an early Carboniferous age by Mr. Gunn,[2] who found that they were restricted in distribution to rocks underlying the Clyde Plateau lavas. In the Campsie Fells they cut the lavas freely, but do not appear among the later sediments, and they are specially abundant in the neighbourhood of the Meikle Bin vent. Their direction appears to be preponderantly E.N.E., but is very irregular.

We may now pass on to a consideration of local features of interest of the volcanic rocks of the plateau as exposed in the Campsie Fells, Kilpatrick Hills and Cathkin Hills respectively, and then deal with the associated vents, dykes and other intrusions.

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[1] *Cf.* Sir Archibald Geikie, 'Ancient Volcanoes of Great Britain,' 1897, vol. i., p. 394.

[2] Quoted by A. Geikie, *loc cit.* p. 407.

Lavas and Tuffs of the Campsie Fells.—The structure of the Campsie Fells is very simple, for it is that of a plateau with a slight general inclination towards the south-east. An excellent opportunity is thus afforded for the study of local variations in the constitution of the volcanic pile.

In the majority of sections lava rests upon lava in almost unbroken succession, but in the Garrel Burn two well-marked beds of tuff are interstratified near the base of the group, while along the northern face of the hills various impersistent masses of tuff and agglomerate put in an appearance. It is very difficult in several cases along this northern front to distinguish the interbedded ashes from those occupying the volcanic pipes of the district. The material in the two cases is of identically the same character, and it seems fairly certain that the exceptional abundance of interbedded pyroclastic material in this locality is the direct result of proximity to the sources of supply. We shall have occasion later on to refer to these northern ash beds when attention is given to the vents with which they are associated. It may be mentioned in passing that the explosive outbursts appear to have been predominantly of the Vulcanian rather than the Strombolian type, since more or less angular blocks of compact lava are common, but bread-crust bombs have not been observed.

Turning now to the arrangement of the lavas which form the bulk of the plateau, we find a more or less definite sequence holding throughout the greater part of the district included within the map. There is a lower group of microporphyritic basalts of Jedburgh type, and an upper group in which macroporphyritic basalts, mostly of Markle type, and also mugearites[1] are abundantly represented. The lower group of Jedburgh basalts occupies the greater part of the surface of the Fells, while the upper, more varied assemblage caps Holehead and Lairs, on the two sides of Campsie Glen, forms the small outlier of the Little Bin and reappears in Craigannet Hill, north-east of the Carron Valley. Owing to the great downthrow of the Campsie fault the upper group also occurs in force in the Kilpatrick Hills, in spite of the fact that these hills nowhere rise so high as the Campsie Fells.

The grouping indicated above is, however, of merely local value. Thus a macroporphyritic basalt of Markle type occurs at the base of the volcanic pile at the north-east corner of the Corrie of Balglass, and another occupies a similar position in the hollow lying east of the Little Bin. Still another is intercalated in the upper portion of the lower group in Campsie Glen, while similar phenomena of interdigitation are met with in Craigannet Hill and less clearly in the March Burn. Lastly, in the southern face of Garrel Hill, the grouping established in the western Campsie Fells breaks down completely.

Special interest attaches to the Garrel section. It has been pointed out already that volcanic activity seems to have originated in this neighbourhood earlier than in the west. In fact the great Cementstone Group is almost unrepresented here, and the volcanic sequence comes on in force a few feet above the summit of the Cornstone Group of the Upper Old Red Sandstone Series. But a markedly different group of lavas occurs here at the base from that which forms the lowest division in the western part of the Campsie Fells. It is an earlier group containing several Markle basalts, with tuffs, a Craiglockhart basalt, and only one Jedburgh basalt.

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[1] The various rock types are described in the petrological section, but it may be mentioned here that mugearites are distinguished in the field by pale weathering tints, and, where not excessively slaggy, by a prominent platy structure. They are seldom conspicuously porphyritic.

In the west the succession is—

(*d*) Upper Group with several Markle Basalts and Mugearites.
(*c*) Lower Group consisting of Jedburgh Basalts.
(*b*) Cementstone Group.
(*a*) Cornstone Group (Upper Old Red Sandstone).

In Lairs Hill, west of Garrel Burn, the succession is—

(d^1) Upper Group characterized by Markle Basalts and Mugearites.
(c^1) Lower Group much reduced in thickness, consisting of Jedburgh Basalts.
(b^1) Still Lower Group characterized by several Markle Basalts.
(a^1) Cornstone Group (Upper Old Red Sandstone).

Slightly further to the east, in Garrel Hill itself, the great Jedburgh basalt group, which in a westerly direction has been followed continuously for a dozen miles, thins away completely, and the Markle basalts, above and below, come together.

It would appear from this that a centre supplying Markle basalts originated somewhere in the Garrel district at a time when the shales and cementstones of the west were being laid down untroubled by any volcanic disturbance. Then were opened the great series of northern necks, of which Dumgoyn may be taken as a type, every one pouring forth basalts of the Jedburgh type and together building up a wide plateau, the base of which rests in the west upon the Spout of Ballagan Sandstone, while in the east it extends some way on to the early Markle basalts of the Garrel district. This complex group of interdigitating cones, gathered about the various Dumgoyn centres, was in turn, wholly or in part, covered by fresh outpourings of lava, chiefly of Markle type, which were likely supplied in some measure from the old Garrel focus reawakened. E. B. B.

We may now give a brief account of the type section of the Campsie Fells, afforded by Campsie Glen and the hillslope to the east leading up to Lairs. The base of the volcanic group is well exposed in the Aldessan tributary burn where it enters the glen. Cementstones and shales, cut by dykes belonging to the volcanic episode, are here overlain by a foot or so of micaceous sandstone, all that remains to represent the Spout of Ballagan position, and above this follow some 10 ft. of fine ash succeeded by the lavas. A thousand feet of the latter intervene between the base of the group in the glen and the cairn at the 1499-ft. level on the hill top. There are, so far as can be judged, 33 lavas in this interval with an average thickness of 30 ft. apiece. The following table gives an approximately correct idea of the sequence represented :—

Upper Group[1]	31-33	Markle Basalts.
	29 and 30	Albite-Keratophyre and Mugearite.
	28	Jedburgh Basalt.
	27	Allied to Mugearite.
	26	Markle Basalt.
	25	Mugearite.
	23 and 24	Markle Basalt.

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[1] On the one-inch Map 25-30 are coloured together as Mugearites.

Lower Group	20-22	Jedburgh Basalts (20 and 22 allied to Mugearite).
	19	Very decomposed, slightly porphyritic.
	18	Markle Basalt.
	1-17	Jedburgh Basalts.

The striking feature of this succession is the homogeneous group of seventeen Jedburgh basalts occurring at the base. These are all exposed in Campsie Glen, where their typical volcanic characters are illustrated with diagrammatic clearness. Their hard central cores and slaggy upper and lower surfaces have in fact determined the picturesque series of waterfalls which add so much to the beauty of the glen. There are also occasional thin beds of red ashy sediment or bole, but these play a quite subordinate *rôle*. None of the lavas included in this type section shows columnar jointing; in fact, columnar jointing is almost unknown among the lavas of the Campsie Fells, although common enough among the intrusions.

The Markle basalt, No. 18, is exposed in the burn slightly above the deep cut of the glen. It is well seen too by the roadside near "Jamie Wright's Well," and is a very handsome rock with large felspar phenocrysts. The rest of the section is based on a traverse between Jamie Wright's Well and the cairn at the 1499-foot level already alluded to.

The Markle basalt horizon represented by 23 and 24 is of special importance. Although along the south face of Lairs there is, as a rule, only one Markle basalt in this position, its conspicuous appearance and relative constancy render it useful as an index from which we may reckon up or down in the sequence. South of the summit of Lairs a thick sheet of typical flow-banded mugearite forms the third flow below the index band, and merits attention, not only as a specially good field example of a mugearite, but also as the source of material of which a chemical analysis has been made (p. 182). E. B. B., E. M. A.

Lavas and Tuffs of the Kilpatrick Hills.—The lower group of Jedburgh basalts, so widely displayed in the western Campsie Fells, is not exposed in that portion of the Kilpatrick Hills included within the Glasgow map. A little to the west, however, in Auchineden Hill, the four lowest lavas are of Jedburgh type and probably represent the group in question, or rather the upper part of it, for even here the lower part may be cut out by the Campsie fault. Above these four Jedburgh basalts of Auchineden Hill there follows a series of macroporphyritic basalts with several intercalated flows of mugearite, but very few of Jedburgh basalt.

This series corresponds to the upper group of the western Campsie Fells, and the opportunities afforded for its study are especially favourable. It is found that the various macroporphyritic lavas vary a good deal among themselves, so that it is an easy matter to distinguish them and, where exposures are good, to map them out. Individual flows do not persist for any great distance, but, owing to an almost constant dip towards the south-east the general sequence is clear enough. Markle basalts are predominant, especially at first, but as we ascend in the series more basic lavas make their appearance, with conspicuous augite and olivine phenocrysts, until about Black Loch[1] and near Boards we find thoroughly basic rocks of the Craiglockhart and Dunsapie types. Above this, in the good exposures south of Strathblane and west of High Craig, macroporphyritic basalts continue, with the Markle type again well represented. In this upper portion of the series, west and south of Craigton, there are also numerous flows of mugearite.

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[1] Black Loch lies beyond the border of the Glasgow Sheet, one and a half miles W.S.W. of Byshot.

On the whole the evidence for the extrusive nature of the Kilpatrick lavas is not very abundant. It is not infrequent, however, to find the tops of the beds exposed, and these are often seen to be exceedingly slaggy. Then, too, the few sections available of the bottoms of the sheets show that their lower surfaces also are slaggy, and that beneath there is often a thin bed of scoriæ.

The beds of lava are almost always broken up by vertical joints which divide the rock into prisms. In the less basic rocks the weathering splits the prisms across and divides them into a series of thin plates or scales; but among the more basic members the cross joints are less frequent, and the rocks weather into spheroids in the usual manner of basalt. Some of the flows are jointed into very regular columns and form striking features in the landscape. Fine examples are to be seen in the neighbourhood of Boards and along the outcrops of beds running southwards to Craigallian. Another well-jointed bed occurs below Milndavie, and can be followed westwards for nearly half a mile along the southern slopes of the Blane Valley.

The bed on which the Farm of Hilton stands is jointed into very perfect prisms which have no regular direction, but appear to radiate from definite points or lines. No particular relation could be made out between the arrangement of these columns and the surfaces of the bed, and it is presumed that the flow is too thick to have allowed the joints to develop normally to the two surfaces in the ordinary way. Before leaving this subject it may be remarked that the regular prismatic jointing is most strikingly developed in the more basic rocks, as those of the Craiglockhart and Dunsapie types.

A few beds of tuff are interstratified between the lavas. The most important of these has a rather irregular V-shaped outcrop, the apex of which lies near High Craigton. It is this outcrop of ash, continued north-eastwards, which has no doubt determined the position of Craigallian Loch and the escarpment east of Carbeth. Other bands of tuff occur and are shown on the map. The rocks are soft red fine-grained basaltic ashes and are easily eroded away. Good exposures are seldom to be found except in the beds of streams, as, for instance, near Craigton. G. W. G.

Lavas and Tuffs of the Cathkin Hills.—The Cathkin Hills district of volcanic rocks forms an area of about eight or nine square miles, with the peculiarity of being surrounded on almost every side by downthrow faults (*see* Chap. IX., p. 202). The ground rises rather rapidly from the faults which form the northern boundary. It is on this side alone that a sequence can be satisfactorily established.

The various flows are entirely basaltic, and two different types are most largely represented; they have been determined by Mr. Bailey as the Dalmeny and Dunsapie types of basalt. The former is not conspicuously porphyritic, but small pseudomorphs with the characteristic outlines of olivine can always be detected in the hand specimen. The pseudomorphs consist most often of iddingsite and oxide of iron; fresh olivine is very seldom apparent.

The Dunsapie type contains marked porphyritic felspar, as well as the olivine pseudomorphs which have been just described. Phenocrysts of augite are also present, but cannot be so easily made out by eye or lens.

The various members of the volcanic group occupy a position some distance down in the Calciferous Sandstone Series. The base of the group is everywhere cut out by the faults which limit the area to the north. The sequence which is visible comprises (1) a set of lavas mainly of the Dalmeny type, overlain by (2) another set mainly of Dunsapie basalts; the upper group passes beneath conglomeratic sediments already described in Chap. III. We shall now consider the series a little more in detail.

The lowest of the lavas which is actually seen is probably the one exposed in the corner formed by the intersection of the two downthrow faults near East and West Castleton. This is a basalt somewhat resembling the Dalmeny type, and appears to be overlain by another flow of similar character. Then follows one of the Dunsapie basalts which are so much in evidence higher up in the sequence. Above this, and up to the base of the succeeding group, the lavas are mainly of Dalmeny type, but one flow of Jedburgh type occurs near Mill Farm and probably continues to the fault at Laigh Netherton.

The base of the overlying group of much more conspicuously porphyritic basalts runs through the Cathkin Braes public park. The lower part of the slope here consists of Dalmeny basalts, the upper of basalts of the Dunsapie type, one of which forms a prominent escarpment. A little further to the east a good section of this portion of the sequence is exposed in the old quarry at Westhills, and the sunk road leading into it. Entering the latter from the eastern corner of the Cathkin Braes park we first cross the outcrops of two flows of Dalmeny type, separated by a few feet of sandy sediment, then a few feet of volcanic ash, evidently water-bearing, and lastly two lavas of Dunsapie type, forming the base of the upper group. If this section may be taken as typical of the dimensions and relations of the various flows in the district, we should estimate the thickness of the separate members to be from 30 to 80 ft., and conclude that they may or may not be separated by ash or sediment, in any case of no great thickness.

Most of the Westhills quarry has been excavated in the upper of the two Dunsapie basalts ; the same lava flow which forms the conspicuous escarpment in the public park. In one part of the quarry it exhibits beautiful columnar structure, which has been described by Mr. R. White Skipsey,[1] who proposed the name "Glasgow Staffa" for the phenomenon. Two varieties of saponite have been obtained from this quarry—"Bowlingite" and "Cathkinite."[2] Other fine examples of columnar structure occur in a Dalmeny basalt belonging to the lower series, which is exposed to the east and north of Fernhill. The former of these exposures seems to be the one figured by Ure ("History of Rutherglen and East Kilbride," p. 270). The upper part of the sequence is more obscure, but at least one flow of Dalmeny character is intercalated among the Dunsapie basalts, south of Westhills. The basalts of the former type which occupy a moderately large area to the south of Muir may also be of the nature of an intercalation, or else their presence may be accounted for by a dome-shaped structure bringing up the lower group. The actual top of the volcanic group is seen in the gorge beneath Kittoch Mill, where the two uppermost members of the series are Dunsapie basalts.

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[1] 'Descriptive notice of the position and character of several of the Igneous Rocks and Minerals in the Northern front of the Cathkin Hills,' *Trans. Geol. Soc. Glasg.*, vol. ii., part i., 1865, p. 41.

[2] *Ibid.*, part ii., 1867, p. 212, J. Wallace Young, 'On the Analysis of a Green Fibrous Mineral from Cathkin.' D. C. Glen and John Young, 'A Geological Excursion to Cathkin Quarries,' *Trans. Geol. Soc. Glasg.*, vol. vii., part i., 1883, p. 166. *See* also same vol., p. 212. . Heddle, 'Mineralogy of Scotland,' vol. ii., 1901, p. 139.

The strip of volcanic rocks which occupies the southern margin of the map, west of the Cathkin Hills, is the northern edge of a large area of Calciferous Sandstone lavas, which extends into Ayrshire. This area will, it is hoped, be dealt with in a memoir explanatory of one-inch Sheet 22. The strip in question is bounded to the north by a large downthrow fault. It includes both macro- and microporphyritic basalts, and also mugearite. E. M. A.

Volcanic Vents.—The volcanic vents included within the Glasgow map all occur in the northern portion of the district. Most of them were mapped by Dr. Jack, and where others have since been added it is generally upon evidence which is somewhat inconclusive.

The important point is that many are quite certain. They reveal themselves as special circumscribed outcrops of tuff, agglomerate, and massive igneous rock, distributed without regard to the stratigraphy of the district. That they are vertical, continuing to a great depth, is most clearly shown by their persistence as surface features in places where erosion has removed all other trace of volcanic accumulation; they may be cut deeply, but they cannot be planed away. Considered in this light, the vents isolated in the heart of the Upper Old Red Sandstone (*see* Fig. 6) may be regarded as specially instructive.

Scenic independence follows geological independence, and the vents of the district are most of them striking features in the landscape. As such they have received distinctive names, and the seven "duns" among them show how serviceable they proved, in olden days, as sites for forts. They are apt to show particularly abrupt and picturesque form where they are surrounded on all sides by older sedimentary strata, as is the case with Dumgoyn and Dumfoyn; but even where they occur in connection with the lavas of the plateau they seldom hide themselves. Dungoil is a landmark none can miss, and the northern front of the Campsie Fells, with its long succession of vents, is obviously no ordinary escarpment.

The largest of the Campsie vents is that of Meikle Bin, which stands in the centre of the Fells. It is roughly oval in shape, and about a mile and a half long. An even longer vent is mapped on the northern face of the Fells between Gairloch Hill and the Little Corrie, but it is narrower and its continuity is doubtful. Most of the vents are much smaller than this.

Turning to another aspect of the question, we find that the great majority of the old volcanic orifices are choked with the Jedburgh type of basalt; these may be termed the Dumgoyn group. In the Meikle Bin and its satellites, on the other hand, trachyte, trachyandesite and trachybasalt are conspicuously represented. The Meikle Bin is otherwise distinguished as the centre of a swarm of short irregular dykes which it is quite impossible to map beyond the limits of the streams in which they are exposed. The Dumgoyn group of vents does not exhibit this feature. E. B. B.

1. The Dumgoyn Group.—The Meikle Caldon, Little Caldon and other vents isolated in the outcrop of the Old Red Sandstone north of the Kilpatrick Hills belong to this group. They are partly filled with ash and partly with intrusions. The fragments in the ash are sometimes six inches across, but are generally much smaller.

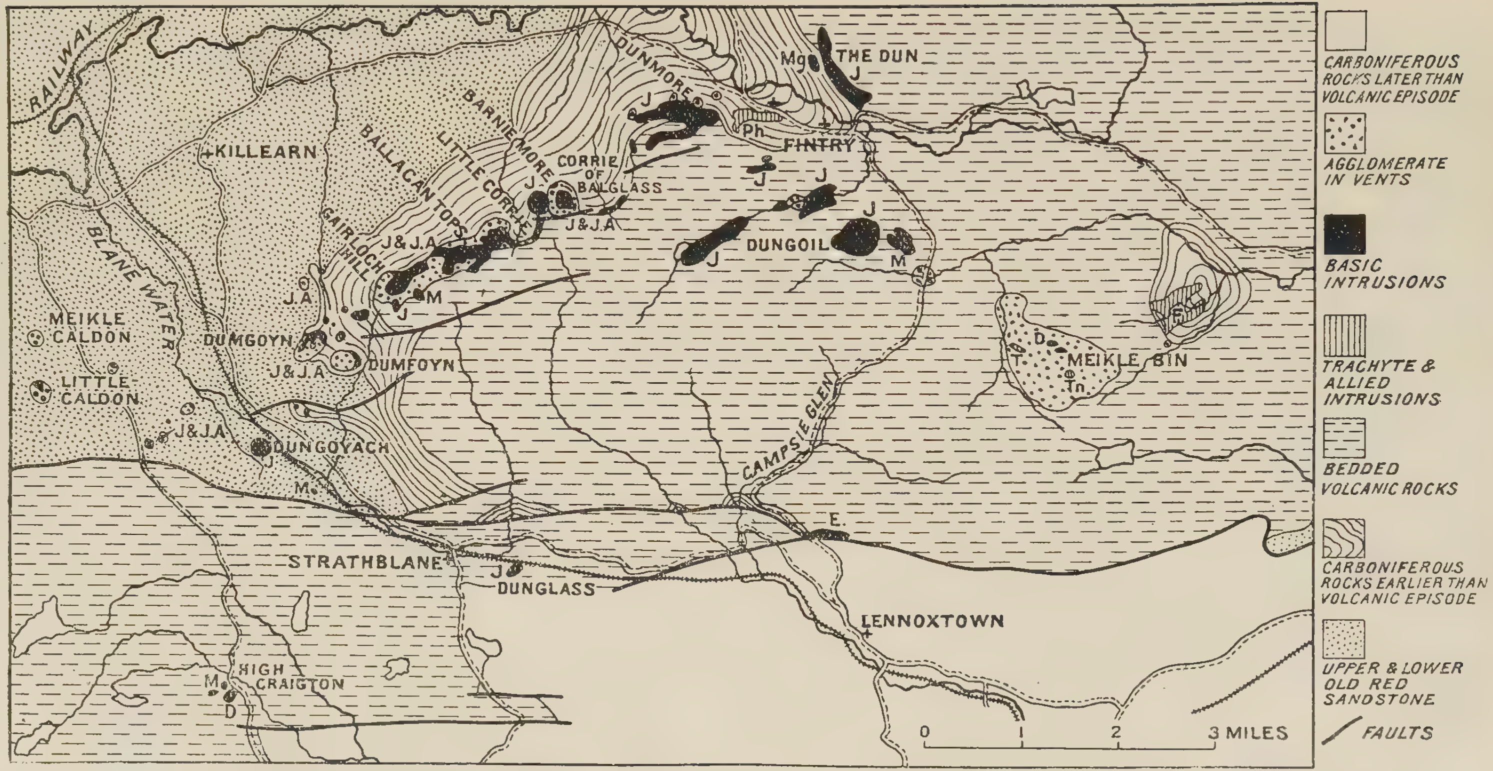

Fig. 6.—Sketch Map showing Vents and Intrusions connected with Volcanic Episode of Campsie Fell District. The Lennoxtown Essexite (E.) of doubtful age is also indicated. J.=Jedburgh Basalt; J.A.=Agglomerate composed of Jedburgh Basalt; M.=Markle Basalt; D.=Dunsapie Basalt and allied Trachybasalt; Mg.=Mugearite; Tn.=Trachyandesite; Ph.=Phonolite; T.=Trachyte; F.=Felsite. All dykes omitted. The intrusive nature of the Dun, Fintry, is doubtful.

Dungoyach, rising abruptly above the floor of the Blane Valley, is peculiar in that it consists of a plug of Jedburgh basalt so much broken by little faults that it has become a "crush-conglomerate," closely simulating a true ash. More than one intrusion may be present in this mass, as internal chilled margins are met with which seem at times to divide slightly different varieties of rock.

Balglass, a straggler of the Dumgoyn group in the same valley, makes a striking feature by the railway side about a mile east of Strathblane station, and cannot be passed over in silence. Its actual relations to the surrounding rocks, which must belong to the Kilpatrick lava sequence, are nowhere exposed, but its topographical isolation and highly developed columnar structure, taken together, mark it as an intrusion. G. W. G.

East of the Blane Valley stand Dumgoyn and Dumfoyn, which have served Sir Archibald Geikie[1] as type illustrations in his writings on this district. Both hills consist of great masses of basaltic agglomerate and intrusions of the Jedburgh type. They are oval in ground plan, and 700 and 500 yds. long respectively. They are mounted upon a shoulder of the same slope that supports the plateau basalts, and the western edge of Dumgoyn reaches down the incline to a well-marked outcrop of pebbly sandstone occupying a known position near the top of the Upper Old Red Sandstone (Fig. 7).

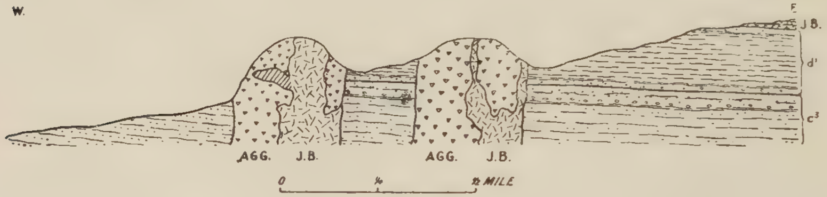

Fig. 7.—Section across the Dumgoyn and Dumfoyn Vents, and the base of the bedded lavas of the Campsie Fells. Agg. = Agglomerate; J.B. = Jedburgh type of basalt; d¹ = Ballagan Group; c³ = Upper Old Red Sandstone.

Part of the intrusion of Jedburgh basalt in Dumgoyn takes the form of a highly columnar sill, and we may remark at once that columnar structure is very commonly developed by Jedburgh basalt intrusions, although very rare among lavas of the same type.

Between Dumgoyn and Gairloch Hill there are numerous small vents which need not detain us here. From Gairloch Hill to the Little Corrie a narrow vent has been mapped with a length of a couple of miles. Its continuity is doubtful, but the face of the hill consists of agglomerate and intrusive columnar basalts precisely recalling the association met with in Dumgoyn. The columnar structure of Ballagan Tops is one of the finest spectacles afforded by the Campsie Fells.

At the west end of Gairloch Hill there is some agglomerate which is obviously not included in a vent, for digging proved that it rests normally upon the Spout of Ballagan Sandstone. It is overlain by a slaggy lava, and is 70 ft. thick in proximity to what is taken as the edge of the vent, while 100 yds. away it has thinned out to 10 ft. or less. This shows that some of the Gairloch agglomerate to the east may also be portion of a cone rather than material infilling a vent.

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[1] *Loc. cit.*, Figs. 123, 124, 127.

Really good sections showing the edge of the agglomerate are not met with before reaching the Little Corrie.[1]

The western spur at the mouth of the Little Corrie is formed of precipices of agglomerate pierced by columnar intrusions. The margin of the agglomerate starting from the south-west corner of the Corrie runs northwards, obliquely across the outcrop of the Spout of Ballagan Sandstone, until it comes into transgressive contact with the underlying Ballagan Shales. This relation furnishes clear evidence that the agglomerate is locally enclosed within a vent.

As at Gairloch Hill, however, it can be shown that the agglomerate also spread out upon the top of the Spout of Ballagan Sandstone, for just in the south-western angle of the corrie it is found in this position. The section is unambiguous, the sandstones are of normal thickness, and rest upon the Ballagan shales beneath. The overlying agglomerate is itself capped by a columnar sill.

The relation just described holds only for a very short distance, and the head of the Little Corrie is backed by intrusive columnar basalt in the west and by equally intrusive agglomerate in the east. The intrusive nature of these rocks is revealed by the manner in which they cut out a large part of the Spout of Ballagan Sandstone.

In the eastern angle of the corrie the agglomerate spreads out laterally to the north over the top of the sandstone, once more developed in full force. The section illustrating the change of relations is admirably clear. The agglomerate, capped by a sill of columnar basalt, is continuously exposed, and is not broken by any fault, but, while its northern portion rests on the sandstone, its southern portion runs down the hill slope right across the course of several prominent beds of the latter. This may be taken as the best example in the Campsie Fells of a vent in connection with the cone which it supplied.

The rest of the corrie face above the sandstone is occupied by the bedded agglomerate, an impersistent lava and a highly columnar sill, until a magnificent example of a columnar basalt plug is met with forming the western half of Barniemore. The almost vertical chilled edge of the plug is well exposed in the corrie wall; the columns of the intrusion, elsewhere steep, bend as they approach the margin to meet it approximately at right angles. Two sheets of breccia, inclined very steeply toward the plug, separate the latter from the truncated outcrops of sandstone and overlying agglomerate, occurring to the south. The breccia consists of agglomerate and broken vesicular basalt, and doubtless represents remnants of earlier eruptions through the same vent.

Leaving the corrie, the face of the plug rises as a fine blocky cliff that showers its debris on to the low ground beneath. At one point it extends into the sandstone group with a level base following the bedding. Further east it terminates, so far as the cliff section is concerned, in a vertical and beautifully banded chilled edge.

In the cliff the chilled edge of the plug comes into contact for some distance with the great mass of agglomerate which, with associated basalts, forms the other half of Barniemore. Near the top of the cliff, however, the two separate for a little, and the agglomerate is shown to have a vertical edge independent of the plug, for between the two a broken remnant of sandstone is preserved : at the foot of the cliff the margins again separate, the one turning to the north-west, the other to the north-east ; again the interval is occupied by sandstone ; and again the transgressive relations of the agglomerate are obvious. It thus seems fairly certain that we are dealing with the margin of an ash neck.

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[1] In the angle of the hillface east of Ballagan Tops the agglomerate is seen upon the top of a massive bed of sandstone; but the latter is in turn underlain by a thick basaltic intrusion, and we have adopted the interpretation that the sandstone here is a detached mass involved in the materials of the vent. In the Little Corrie to the east a considerably larger mass is seen to be enveloped completely in agglomerate.

The contents of the vent are well displayed in a stream section immediately to the east. The agglomerate is well bedded, and much of it ranges to a fine tuff in texture. Near the margin it overlies a lava-form basalt, which comes in contact with the sandstone outside ; further in it is pierced by an irregular intrusion, so slaggy in parts that it cannot have consolidated under any great pressure. Above this intrusion, which is in large measure massive, the agglomerate is especially coarse, but still well bedded ; it is overlain by basalt with very perfect columnar structure—a portion of a great mass forming an almost continuous capping to the vent. The basalt is best seen along the western face of the Corrie of Balglass, where its blocky columnar jointing is especially conspicuous. Although this massive basalt in its general characters exactly resembles the intrusions of the Campsie Fells and has been mapped as such, it is not certain whether it is not a lava everywhere along the face of the corrie, since its base is always somewhat ropy and vesicular. In the angle of the corrie, where it rapidly tapers out, it certainly is a lava, for, losing its columnar jointing, it becomes ropy and vesicular throughout, with an approach to pillowy structure, and with interstices filled in with a purple shale which at this point is interbedded with the agglomerate.

Just about this position, so far as can be judged, the neck ends, and its contents in part, apparently, merge into the bedded volcanic rocks outside. The section is complicated by three faults with horizontal shift which affect the details of the succession in a remarkable manner, showing the great variation of the several rock masses in their lateral extension. A fine exposure of columnar basalt occurs here just in the angle of the corrie at the foot of the cliff ; it seems to be a plug, spreading out above as a sheet, and where brecciated by the horizontal faults gives good examples of pseudo-conglomerate. It is overlain by a purple slag which appears to be the later of the two rocks and is locally of great thickness.

Beyond the last and most conspicuous of the faults the corrie face consists of a noble cliff of bedded basalts. There is, at first, a thin band of agglomerate near the base of the series, but even this dies out against the slaggy termination of a lava flow by the side of the stream which plunges into the corrie at its head. Other agglomerate beds, however, make their appearance and thicken rapidly towards Dunmore. Before leaving the corrie we may draw attention to an intrusive mass at its head, and another at the eastern entrance ; the latter occurs as a sill of no great extent, but is distinguished by its very perfect columnar structure.

The Dunmore basalt is clearly an intrusion, for its margins are highly transgressive. It is probably an irregular plug expanding into sheets at various levels. It exhibits a well-marked vertical, blocky, columnar structure.

Various other intrusions may be included with the Dumgoyn group of vents, but the only one of great importance is Dungoil. This mass has a blocky columnar structure similar to that of Dunmore. It stands as a conspicuous landmark from among the surrounding lavas, and its transgressive character is clearly shown along its eastern margin.

2. The Meikle Bin Vents.—The Meikle Bin is a conical hill rising in the midst of the Campsie Fells. The absence of terrace featuring suggests, even at a distance, that this hill is quite distinct from the lava masses round about. Careful examination of its grassy slopes reveals, moreover, enough exposures to show that the hill mainly consists of fine tuff. Coarse agglomerate, with great blocks of rather porphyritic trachybasalt, is also exposed in the upper of two glacial drainage channels which breach the northern spur of the hill. An intrusion of similar porphyritic trachybasalt allied to the Dunsapie type of basalt, makes a prominent shoulder on the north-west face of the hill, and a trachyandesite mass rises as a little peak near the summit of the hill. Yellow and pink trachytes and felsites[1] occur in great profusion in the form of small dykes and irregular masses, often vesicular. Fragments of these acid rocks can also be recognized among the tuffs.

The margins of the vent are nowhere exposed, and it is quite possible that the great hollow to the north-west should be included. Sir Archibald Geikie always regarded this hollow as a vent, although he was unaware of the great extent of the neighbouring Meikle Bin neck.

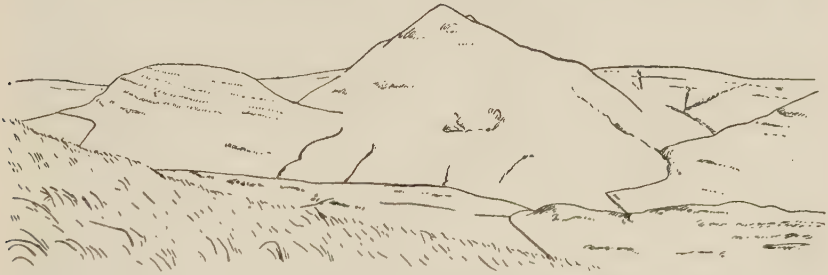

FIG. 8.—Meikle Bin (volcanic vent, mostly tuff) and Little Bin (bedded lavas), as seen from the North.

The small outcrop of ash, exposed in the Clachie Burn where it crosses the road, has been mapped as a vent on account of the similarity of the tuff to that of Meikle Bin; its relations are, however, not clearly exposed.

Dykes of the Volcanic Episode.—One of the most striking features of the Meikle Bin centre is the extraordinary profusion of dykes found in connection with it. They cut the tuff of the vent in great numbers, and also traverse the lavas of the vicinity. Basalts, with and without conspicuous phenocrysts, trachytes, and felsites all occur, and are well exposed in the stream immediately west of the Bin.

In the hollow to the north-west of the Bin, exposures show a complex of interlacing dykes with little or no country rock between. Markle basalts are specially abundant in this complex, and one of them, exposed in the stream south-west of Waterhead, is remarkably xenolithic, including fragments of quartzite, sandstone and igneous rocks.

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[1] The trachytes of this district have been recorded by Sir Archibald Geikie, *loc. cit.* p. 406, and Mr. A. V. Lothian, 'The Petrology of the Kilsyth Hills,' (published privately 1902), pp. 11-14 and 25. Sir A. Geikie has also described the felsites, *cf.* 'On the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,' *Trans. Roy. Soc. Edin.*, vol. xxix., 1880, p. 510.

Away from the Meikle Bin centre, dykes are less abundant, more especially the acid types. There are certainly very few trachyte or felsite dykes three miles away from the focus, and only one has been found in the Western Campsie Fells and the Kilpatrick Hills. The basic dykes persist over a wider area, the limits of which are not fully known.

It is very difficult to get any idea of the general direction of these dykes. They are seen only in isolated exposures and can seldom be mapped for any considerable distance. Their direction is very irregular, but perhaps more often E.N.E. than anything else.

Petrologically the basic dykes correspond with the various lava types known in the Fells. The acid dykes, to judge from the nature of the contents of the Meikle Bin vent, correspond with lavas which were ejected at a late stage in the development of the plateau and have since been entirely removed by denudation. E. B. B.

The dykes are only a few feet thick, as a rule, and except where they come down the bare escarpments, they fail to show at all in the landscape. In spite of their numbers there is, in fact, only one which is in the least conspicuous. This is a thick felsite which cuts down through the Lairs escarpment north-east of Lennoxtown. It is perhaps better described as a highly inclined sheet than a dyke. Its central portion is beautifully columnar, while its margins exhibit the most perfect fluxion structure. A little dyke of porphyritic basalt cuts this felsite, but it is very doubtful whether the basic dykes as a whole are later than their acid associates. E. M. A.

Ungrouped Intrusions of the Volcanic Episode.—An irregular intrusion of phonolite occurs south of the road at Newton o' Fintry. The rock is opened up in a large quarry, but for fresh material one must hammer the knobs by the roadside at the east end of the village. It is crossed by two narrow basic dykes exposed in the quarry.

A much decomposed felsite is found in the central hollow of the Campsie Fells, where denudation has laid bare the sediments underlying the volcanic pile. The structure of this part of the district is that of a dome, with rather steep dips along the western side, so that it is not improbable that the felsite exposed may be the upper portion of a laccolith.

A coarsely crystalline Markle dolerite has been mapped immediately east of Dungoil. It appears to be intrusive, and is perhaps a plug.

A Markle basalt is also found intrusive in Clachertyfarlie Knowes, close to Gairloch Hill, in the very heart of the district occupied by the Dumgoyn group of necks. E. B. B.

In the Kilpatrick Hills there are several little irregular intrusions penetrating a bed of tuff near High Craigton. The most important consists of a basic rock approaching the Dunsapie type, which has been quarried chiefly for road metal. In the quarry the mass is jointed into thin columns which have different directions in different parts of the quarry. The margin of the intrusion is well seen south of the stream, where it forms a vertical wall and displays the usual characters; at the actual margin there is platy jointing parallel to the surface, and, further in, are columns arranged at right angles to the same. On the south side the margin is not seen, and the lines laid down on the map are purely conjectural. A small dyke-like intrusion, running in a general east-and-west direction with transverse columns, occurs west of the larger intrusion, and though the two masses are separated by tuff seen in the stream, they must be intimately related to one another. The rock is of similar character in both masses. Associated with these two intrusions is an elongated plug having a general north and south trend. Its relations to the larger mass have not been made out. The junction with the surrounding tuff can be seen at its south end near the stream. The rock is jointed up into rude slabs, and at the south end assumes a vertical platy structure running north and south which would seem to be cut off by the mass to the south. In the hand specimen the rock is a finely crystalline Markle basalt with abundant small phenocrysts of plagioclase. A plug of somewhat similar rock occurs near Arkhaven in the Blane Valley. G. W. G.

II. INTRUSIONS NOT DEFINITELY CORRELATED WITH THE VOLCANIC EPISODE.

With the exception of the Lennoxtown essexite (1), which occurs as a small elongated plug or boss, all the intrusions considered here are either sills or dykes, and may be classified as follows :—

(2) The quartz-dolerite intrusions, including the Kilsyth[1] and perhaps the Milngavie sills and also several broad east-and-west dykes.

(3) The teschenitic sills of Cathcart, Glasgow and Paisley.[2]

(4) The narrow W.N.W. olivine-dolerite dykes of the Baillieston district.

The consideration of the age of these various intrusions at once carries us beyond the limits of the Glasgow map.

(1) The Lennoxtown essexite may easily belong to the volcanic episode of Calciferous Sandstone times; but a similar rock at Crawfordjohn is generally regarded as Tertiary.

(2) The full discussion of the age of the quartz-dolerite intrusions will be deferred until it will be possible to enter into details regarding the great sill complex of Stirling, Kilsyth, Hillend and Linlithgow. The petrological identity of this sill complex with the east-and-west dykes is now a well established fact,[3] and several authors, beginning with Dr. Clough,[4] have suggested that both the sills and dykes belong to a single intrusion period. The field evidence in support of this position is strong, though none too abundant, and is based upon the variable behaviour of the dykes and sills *inter se*. In one case, in the Kilsyth district, a dyke appears to cut a sill (*cf.* Dr. Crampton, p. 157), while in another case, in the Bathgate Hills, a member of the sill complex cuts a dyke.[5]

To these two instances we may add the special relation of the sill complex as a whole to the Lenzie-Torphichen dyke.[6] The sill complex takes a sudden jump at this dyke from lower horizons, on the north, to higher horizons, on the south. Dr. Peach was the first to recognize this relation in the neighbourhood of Torphichen, and during the recent revision Dr. Crampton has found evidence that it also holds good in the Mollinburn district.[1] The explanation Dr. Peach has suggested is that the sill complex has in large measure proceeded from this particular east-and-west dyke, spreading out on different stratigraphical levels on the two sides of the fissure.

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[1] Kilsyth lies a little east of the map.

[2] Paisley lies a little west of the map.

[3] J. J. H. Teall, quoted by C. T. Clough, 'The Geology of Cowal,' *Mem. Geol. Surv.*, 1897, p. 157. J. D. Falconer, 'The Igneous Geology of the Bathgate Hills,' *Trans. Roy. Soc. Edin.*, 1906, vol. xlv., 1908, p. 137. J. S. Flett and G. W. Grabham *in* 'The Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, pp. 273, 301. G. W. Tyrrell, 'Geology and Petrology of the Intrusions of the Kilsyth-Croy District, Dumbartonshire,' *Geol. Mag.*, 1909, p. 305.

[4] *Loc. cit.*, p. 147. *See also* Falconer, Grabham and Tyrrell.

[5] C. T. Clough, Summary of Progress for 1904, *Mem. Geol. Surv.*, 1905, p. 118.

[6] *See* p. 158.

The quartz-dolerite sills have almost certainly been folded, and in some cases faulted, along with the sediments into which they have been intruded. The evidence afforded by the Kilsyth sills demonstrates considerable post-faulting intrusion; but pre-faulting intrusion is almost equally clear near Ravenscraig in the Bathgate Hills.[2] Many of the dykes coincide with faults as if guided by the fault fissures (*e.g.*, near Milton, p. 157). It would appear probable then that the faulting and the intrusion were in a general way contemporaneous.[3]

It is exceedingly probable that much of the folding and faulting, to which attention has been directed in the previous paragraph, occurred at about the same time as the well-marked disturbances that intervened between the Carboniferous and Permian of the north-east of England. On this account, the quartz-dolerite suite of the Forth and Clyde valley is commonly classed as pre-Permian, or Permo-Carboniferous. On the other hand, since the appearance of the first edition of this memoir, it has been increasingly realized that quartz-dolerite is a characteristic Tertiary rock-type in the West of Scotland; and Dr. Tyrrell[4] has tentatively suggested that the Forth and Clyde quartz-dolerites may, after all, be Tertiary,—a view to which, all along, Sir Archibald Geikie has inclined in regard to the East-and-West dykes. It seems advisable, therefore, to amplify the evidence outlined above, and to discuss in connection with it (par. *e*) a very important additional clue supplied by Mrs. Wallace:—

(*a*) The Scottish sills and East-and-West dykes under consideration belong to one period of intrusion, and are contemporaneous, as a suite, with some of the more important movements that have affected the Carboniferous.

(*b*) The sills are probably merely a continuation of what is known across the Border, as the Whin Sill of the North of England. Regarding this latter, Sir Jethro Teall[5] has written:—"It must be posterior to the Lower Carboniferous period and anterior to the disturbances which have affected the district. This seems to imply that it is post-Carboniferous and pre-Permian." Later work leaves this conclusion unchallenged, even by those who have shown that the English Whin Sill (like its supposed Scottish representatives) is later than a considerable share of the faulting which it encounters.[6]

(*c*) It seems that the East-and-West dykes of Scotland can also be matched in England; for Teall believes, on petrographical grounds, that a few more or less east-north-easterly dykes in the North of England are referable to the same period of intrusion as the Whin Sill.[1] The most noteworthy among them is the Hett dyke.[2] It has been traced for 23 miles through Carboniferous rocks, including Coal Measures; and yet it fails to cut Permian rocks, under which it has been followed in coal mines, a few miles east of Durham. In the eastern part of its course, it is flanked at a distance of 2 miles, by a parallel dyke of similar type, with an underground connecting sill between. This companion dyke also passes under Permian without cutting it. No one questions that Sedgwick[3] was justified in his cautious deduction that the Hett dyke is probably, though not certainly, pre-Permian.

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[1] *See* p. 153.

[2] E. B. Bailey in 'The Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, Fig. 19, p. 285.

[3] G. W. Tyrrell, *loc. cit.*, p. 304. *See also* below p. 156.

[4] G. W. Tyrrell, 'Classification and Age of the Analcite-bearing Igneous Rocks of Scotland,' *Geol. Mag.*, vol. lx., 1923, p. 258.

[5] J. J. H. Teall, 'British Petrography,' 1888, p. 207.

[6] W. Gunn, 'The Geology of Belford, Holy Island, and the Farne Islands, Northumberland,' *Mem. Geol. Surv.*, 1900, p. 97.

(*d*) Some of the East-and-West quartz-dolerite dykes of the Forth and Clyde have been traced by Clough and others across the south-west Highlands. At every exposed contact they are cut by the north-west Tertiary dykes of the Mull Swarm.

(*e*) Quartz-dolerite blocks, sometimes with hypersthene, have been obtained from ash necks in East Fife.[4] These particular necks are generally referred to the Permian, as developed in Ayrshire. Mr. Balsillie, however, regards them as Lower Carboniferous; and he correlates their enclosures of quartz-dolerite with quartz-dolerite intrusions occurring in Forfarshire, for which he suggests an Old Red Sandstone date. If Mr. Balsillie is correct, the quartz-dolerite fragments of the Fife necks have no bearing upon the age of the quartz-dolerite suite of the Forth and Clyde, since members of this suite freely cut Coal Measures. The present writer does not follow Mr. Balsillie in this particular, and agrees with Mrs. Wallace in regarding the fragments as an additional suggestion in favour of the Permo-Carboniferous date of the Forth and Clyde suite. At the same time, it is very difficult to form a definite opinion on so difficult a subject. Sir Archibald Geikie[5] has described and figured an east-and-west dolerite dyke cutting the Kingask ash neck of East Fife; and, as Mr. Balsillie points out, this dyke belongs to the quartz-dolerite suite. Perhaps the simplest explanation is to suppose that:—the Kingask neck is of Lower Carboniferous age—the existence of such necks in East Fife will readily be conceded since Mr. Balsillie's work on Largo Law; the quartz-dolerite suite is of Permo-Carboniferous age; and the necks containing quartz-dolerite fragments are of Permian age.

(3) The teschenitic magma is distinguished petrologically from the quartz-dolerite magma by a relatively greater content of alkali. It is distinguished in its field relations, as displayed in the Glasgow

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[1] J. J. H. Teall, 'British Petrography,' 1888, p. 206.

[2] J. J. H. Teall, 'Petrological Notes on some North-of-England Dykes,' *Quart. Journ. Geol. Soc.*, vol. xl., 1884, p. 230; *see also* 'British Petrography.'

[3] A. Sedgwick, 'On the Geological Structure and Internal Relations of the Magnesian Limestone,' *Trans. Geol. Soc.*, 2nd ser., vol. iii., 1835, p. 63.

[4] I. F. Wallace (*née* Stewart), 'Notes on the Petrology of the Agglomerates and Hypabyssal Intrusions between Largo and St. Monan's,' *Trans. Geol. Soc. Edin.*, vol. x., 1916, pp. 357, 359, 360; *and* D. Balsillie, 'Further Observations on the Volcanic Geology of East Fife,' *Geol. Mag.*, vol. lx., 1923, p. 541.

[5] A. Geikie *in* 'The Geology of Eastern Fife,' *Mem. Geol. Surv.*, 1902, p. 198.

district and the Lothians, by its *never* occurring in the form of great east-and-west dykes: this shows that the two magmas were available at different periods. In two instances in the East of Scotland, quartz-dolerite dykes cut teschenitic sills,[1] and it is thus evident that there was an intrusion period for teschenitic magma prior to that which ushered in the quartz-dolerite.[2] In the West of Scotland, Dr. Tyrrell[3] has obtained good evidence that many teschenitic sills may belong to the Permian of Ayrshire. As matters stand, the writer thinks it probable that:—(1) the teschenitic intrusions of the Forth and Clyde region are of various dates, corresponding with volcanic episodes in the Carboniferous and Permian; and (2) the main quartz-dolerite suite of the same district is Permo-Carboniferous.

(4) With regard to the Baillieston dykes, Dr. Clough points out that they almost certainly belong to the great suite of north-west dykes so abundantly developed in connection with the various Tertiary volcanic centres of the West Highlands.

The individual intrusions will now be dealt with in the following order—(1) The Lennoxtown essexite; (2) the quartz-dolerite sills and dykes; (3) the various teschenitic sills; and (4) the W.N.W dykes of the Baillieston district.

(1) *The Lennoxtown Essexite.*—This rock occurs as an elongated plug or small boss, 700 yds. long and 100 yds. wide. It is well exposed by the side of the road leading across the hill a mile north of Lennoxtown. At one point on the slope above the road it clearly truncates the step features of the bedded lavas, and is found. on close examination, to be tolerably coarse right up to the margin without any marked sign of chilling. To the south, it must come in contact with the Campsie fault, but from lack of exposure it has not been ascertained whether the intrusion is cut by this dislocation or no; it certainly has not been guided by the fault, for the two diverge obliquely when followed to the east.

The greater part of the intrusion resembles a normal fine-grained gabbro or coarse dolerite in appearance. A beautiful porphyritic type is, however, exposed by the roadside near the limestone workings, with idiomorphic augite crystals measuring a quarter of an inch across. Further up the road the rock is in a very disintegrated condition, and carries conspicuous flakes of biotite; it is also crossed by one or two aplitic veins.

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[1] A. Stenhouse and R. Campbell, 'The Geology of Inchcolm,' *Trans. Geol. Soc. Edin.*, vol. ix., 1910, p. 130. H. B. Maufe, 'The Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, p. 282.

[2] *Cf.* R. G. Carruthers, 'Oil-Shales of the Lothians,' *Mem. Geol. Surv.*, 1912, pp. 2, 14, 15.

[3] G. W. Tyrrell, 'The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland,' *Trans. Geol. Soc. Glasg*, vol. xiii., part iii., 1909, p. 311; and 'Classification and Age of the Analcite-bearing Igneous Rocks of Scotland,' *Geol. Mag.*, vol. lx., 1923, p. 249. Dr. Tyrrell has made a slip, when he says, *Geol. Mag.*, 1924, p. 142, 'Many of the analcite-basalts and monchiquites, as well as teschenites, of East Lothian are stated in the East Lothian Memoir to be intrusive into the upper part of the Carboniferous Limestone Series.' The Gosford Bay Teschenite is intruded into the lower part of this series, while the other rocks referred to all lie below the top of the Calciferous Sandstone Series. In two cases, to which the writer's attention was directed by Mr. Cuthbert Day, analcite-basalts exposed on the Gullane and North Berwick shore, are, to all appearances, veined by Calciferous Sandstone sediments.

From its very close petrological affinity to the Craiglockhart type of basalts locally developed in the Kilpatrick lava sequence, it is probable that this essexite intrusion belongs to the volcanic epoch. If so, it stands by itself among the "volcanic" intrusions; and on this account, and also because of its particular interest from the petrological standpoint, it is wiser in the meantime not to dogmatize with regard to its age. E. B. B.

(2a) *The Kilsyth Quartz-Dolerite Sills.*—The quartz-dolerite that appears at the eastern side of the special map of the Glasgow district is only part of a larger exposure, occupying at the surface an area of fully 2½ square miles, which outcrops on the flanks of the "Riggin" anticline (p. 194) to the south and east of Kilsyth. Since it was not possible to give a proper account of this intrusion without reference to places beyond the margin of the Glasgow Sheet, a sketch map was inserted in the first edition of this memoir. Later information has introduced some modification into the mapping of this complicated region, and reference should be made instead to the recently published edition of one-inch Sheet 31 (1924).

These quartz-dolerite sills continue underground from the "Riggin" exposures beneath a much more extensive region, including the whole of the detached portion of Dumbartonshire and parts of Stirlingshire and Lanarkshire adjacent, in which their existence has been demonstrated by mining operations. It has been proved that throughout this area, as far downwards as the strata have been explored (in one instance down to the Blackhall Limestone), there is one main sill, lying at various different horizons in the sequence, but rarely more than 40 or 50 fms. from the Index Limestone, and either above or below that seam; while an extra and usually much thinner sill was intruded at a higher level—above the Lyoncross Limestone—in the southern and eastern part of the district.

The area to which these statements apply, and which is considered in the following account, is bounded abruptly on the south by the Lenzie-Torphichen east-and-west dyke (p. 158), beyond which the only known sill lies at very much higher stratigraphic levels—above the Calmy Limestone. The explanation of this sudden change is clearly that which has already been given (p. 150)—this dyke is one of the feeders of, and contemporaneous with, the sills on either side of it.

The variations in thickness of the main sill, as shown by numerous bore records, exhibit a certain rough regularity. The maximum known figure, 50¼ fms., occurred in a bore ⅓ mile W.S.W. of Dullatur Station. Thicknesses above 40 fms. are commonest on the eastern flank of the Riggin, between Dullatur, Cumbernauld, and Low Banton; near Croy the average is 33 fms. and further south-west 20 fms. When traced westwards, the sill shows clear attenuation; thus around Wester Gartshore it varies between 10 and 20 fms., and farther north, while it reaches 25 fms. between Kilsyth and Twechar, it is 20 at Dumbreck, 16 around Gavell, 13 at Inchterf and Shirva, 8 to 12 around Auchinreoch House, 3 to 5 west of the same, and is only 12 ft. 4 in. at Birdston; one mile farther west near Hayston it appears to have died out altogether, and is not met with at Torrance or Cadder. This intrusion is nearly always in one part, but locally—chiefly in the west—divides into two or even three portions, never much separated from each other.

Little is known about the upper sill, which outcrops in a relatively unexplored part of the area. It is absent at Cumbernauld and on the west side of the Riggin, though at Inchterf its usual horizon, above the

Lyoncross Limestone, is occupied locally by the main intrusion. A gradual change of stratigraphic level appears to take place north of Condorrat, but its position in the sequence here is not known with any exactitude. South of the village, though absent at Dalshannan, the upper sill is met with again near Badenheath, where it is $5\frac{1}{3}$ fms. thick and 5 or 10 fms. below the Lyoncross, and S.E. of Barbeth it is exposed at the side of the Luggie Water, and has been proved in a bore, $3\frac{1}{2}$ fms. thick, at its usual horizon. The maximum known thickness is $9\frac{1}{3}$ fms., found in a bore N.W. of Airdriehead. Wherever the upper sill is known, the main sill is invariably found beneath it.

Throughout that part of the Riggin which lies north of the Gavell-Croy faults, westward to Queenzieburn, northward to Low Banton, and eastward to Dullatur and Cumbernauld, the main sill in every known bore is intruded at a horizon *below* the Index Limestone, with the exception of a small tract near Auchinbee.[1] The same statement holds south of the St. Flanan fault as far as the Lenzie-Torphichen dyke, westward so far as the sill is known near Kirkintilloch, and eastward also, except between Condorrat and Mollinburn. But in the ground between the two faults mentioned, from Croy westward past Twechar, Shirva, and Auchinreoch to Birdston, the main intrusion lies invariably *above* the Index,[2] excepting only on the very axis of the Riggin at Barr Hill.

If the last-mentioned exception be disregarded for the moment, it will be observed that the contrast of horizon persists over an area of some 20 square miles. This is in itself a striking fact, highly suggestive of the conclusion that these two fractures were at least initiated before the intrusion of the quartz-dolerite sills; but in the case of the Croy fault this conclusion becomes practically a certainty when the evidence presented in Fig. 12 is considered. It is there shown that the sill has passed straight across a large fault without any notable change of level above Ordnance Datum: east of the fault the strata are thrown up 60 fms., and the sill descends just this amount in the sequence.[3] Subsequent faulting along this line, if any, must have been relatively minute.

Similar behaviour of the sill appears to take place at the next fault on the map northwards; this has a throw which between Nethercroy Pits and Dullatur is believed to vary from 23 to 40 fms., but may be larger. On the surface no definite sign of faulting can be detected across the sill, but while on the south side the intrusion lies between the Haughrigg Coal and the Neilston Blackband Ironstone, across the upthrow it lies about 50 fms. lower in the sequence, just below the Black Metals. The sill has passed across the fault with little or no change of distance above sea-level, but with marked change of stratigraphical horizon, and thus cannot be earlier than the fracture. Something of the same kind takes place near the St. Flanan fault between East and West Board, though the evidence is not sufficiently clear to show whether the horizon may not change at the East Board dyke rather than at the fault.

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[1] The irregular southern end of the dolerite outcrop between the Index and Lyoncross seams is intended to indicate our ignorance of the manner in which the sill changes horizon in this neighbourhood. (*See also* Fig. 12, near east end).

[2] The intersection of the outcrop of this sill with that of the Index, a short distance N.E. of Twechar, is only a diagrammatic representation of the change of horizon in this vicinity; there is no evidence that the place of change lies south of the Gavell fault.

[3] For a similar occurrence in Northumberland, *see* Summary of Progress for 1923, *Mem. Geol. Surv.*, 1924, pp. 84-86.

In another class of instances the sill appears not to have passed straight across the dislocations, but to have jumped to a different level both stratigraphic and geodetic. It has been seen that this may be the case at the Nethercroy-Dullatur fault. A good example occurs near the St. Flanan coal pits, where the strata are thrown down 300 fms. to north, while the sill descends only about 140 fms lower from the surface to a horizon 160 fms. higher in the sequence. The sill above the Index at Twechar, which is found below that seam north of the Gavell fault, probably changes horizon in a similar manner.[1]

Both groups of cases point to the same conclusion : that the incoming of the sill is later, or at least not earlier, than the cross-faults of the Riggin. Consequently in those places where the outcrops of sill on the two sides of a fault are contiguous, the position of the latter at the surface is obliterated and is therefore omitted on the one-inch Map (Sheet 31) ; where the two outcrops are not contiguous, each ends against the fault, and these cases can only be distinguished from those where a fault is later than a sill by examining the horizon at which the latter is intruded on either side : the intervening portion of fault may be occupied by a connecting dyke, but no certain evidence on this point is yet known in the Kilsyth district.

As noted in a previous paragraph, the constancy of the main intrusion at a horizon above the Index Limestone between the Gavell-Croy and St. Flanan faults appears subject to an important exception on the anticlinal axis, where the sill exposed in Barr Hill Wood is known to lie between the Haughrigg and Kilsyth Coking coals. Eastwards this sill maintains the same position to beyond Gartshore Nos. 5 and 6 Pits, where it suddenly jumps above the Index (Fig. 12, p. 195) ; westwards, the apparent absence, in Twechar No. 2 Pit, and again in Gartshore No. 10 shaft, ¼ mile to W.S.W., of any intrusion between the same two coals, coupled with the presence of a thick sill above the Index, suggests that the intrusion has once more jumped more or less suddenly to the higher horizon, this time in a westerly direction. In the area between the two faults mentioned, the sill thus lies below the Index only, it would seem, in the immediate neighbourhood of Barr Hill, and near the axis of the Riggin in one of the places where the plication is most intense (p. 194). Such localization is reasonably to be explained only if the intrusion was not earlier than the folding. This explanation is still required even if the sill above the Index was continuous at that horizon also right across the now denuded anticline ; but it is perhaps more probable that such was not the case, and that on approaching the Riggin axis from both sides the dolerite abandoned its high stratigraphic level and broke across the strained and possibly fractured sediments into the lower horizon at which it is now found on Barr Hill. It should be noted that the sudden changes of horizon here referred to seem to occur along lines, more or less parallel to the direction of folding, beneath which the strata are unfaulted, and are thus of a different nature to those described in the preceding paragraphs, which take place along transverse faults, proved in the underground workings.

While it would appear from what has just been said that at Barr Hill the sills are perhaps not earlier than the folding, the evidence to be gathered from the greater part of the Riggin can scarcely be explained otherwise than on the assumption that in general the intrusions are either earlier or at least not later than the plication. This is sufficiently clear from a glance at the one-inch Map, on which the main sill, lying everywhere below the Index Limestone,[1] *i.e.*, in the Limestone Coal Group, is seen to outcrop only where that group appears at the surface, though known to exist over a very much larger area; while, near Townhead Reservoir, it is found on both flanks of the main anticline and of the adjoining syncline to west. But it has been shown above that the sills are often later than the faulting, while the latter again (p. 196) appears to be not earlier than the folding, so that by another line of argument the sills are partly later than the folding. The proper conclusion from the evidence available seems to be that, taken as a whole, folding, faulting and sill-intrusion were all more or less contemporaneous[2] (*cf.* p. 150), and our knowledge of their relation to the east-and-west dykes (pp. 149 and 157) leads us to assign them to the same period.

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[1] *See* p. **154**, footnote 2.

C. H. D.

(2b) *The East-and-West Quartz-Dolerite Dykes.*—One of the chief characteristics of the east-and-west dykes is their great width. They not uncommonly measure 40 to 50 yds. across, or even more, and this, added to the fact thay they do not occur in close proximity to one another, makes it comparatively easy to follow individual members of the series. As a result, it is now known that the Campsie dyke continues, with scarce a break, from Clyde to Forth—that is, for more than thirty miles, while others of the group have been traced for even greater distances.

The Campsie Dyke.—This dyke is first exposed in the Glasgow Sheet at Ballewan, in Strathblane. It has been quarried here and is about 60 ft. thick, while there is another parallel intrusion about a quarter of a mile further south, which, however, does not run far. The main dyke can be followed eastward without difficulty into the Campsie Fells. It seems to have extended apophyses locally into the lavas, for a sheet of quartz-dolerite is exposed among the latter in Fin Glen, not far below the point where the dyke crosses the stream. The Alvain Burn, where it enters the Campsie Glen, gives a very good exposure of the dyke, in which its coarse doleritic nature is well displayed.

South of Meikle Bin, further to the east, there is again a flanking dyke, but this time on the north side of the main intrusion. It may be mentioned that there is little or no faulting along the line of the Campsie Dyke.

E. B. B.

The Kilsyth Dykes.—A group of three dykes occurs in the Kilsyth district:—

The Dullatur Dyke.—This is the northernmost of the Kilsyth dykes, It crosses the railway a quarter of a mile east of Dullatur Station. With the exception of a small area near the canal, it has been traced completely through the "Riggin" in underground workings, but it cannot be distinguished in the dolerite exposures at the surface. Between Hunterston and Drumairn, a dyke, probably representing the same intrusion, appears at the surface and can be traced in the same direction for a mile and a half further west, being well exposed in the burns south of Spouthead. This Dullatur dyke measures 100 ft. across in the workings near Kilsyth, and has burnt the coals for a distance of 100 ft. on either side.[1]

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[1] Except between the Gavell-Croy and St. Flanan faults, as already noticed.

[2] This appears to be the case also in West Fife. *See* Summary of Progress for 1923, *Mem. Geol. Surv.*, 1924, pp. 125, 126.

The Croy and Milton Dyke.—About a mile further to the south, this dyke is exposed in the railway cutting between Dullatur and Croy, and traverses the "Riggin" in the Nethercroy district, its position in the workings being well known for a distance of nearly a mile. In one place it occurs in two parallel intrusions having a total thickness of 99 ft.

The position of this dyke at the surface is perhaps indicated by a deep hollow feature, which follows the course of the dyke through the sill directly above the underground position of the former. The actual junction between dyke and sill is nowhere visible, but the evidence afforded by the position and character of the hollow is highly suggestive that the dyke is later than and cuts the sill. This intrusion has been followed westward continuously to a point south of Auchinstarry, where it dies out before reaching the ironstone workings near Strone. A short dyke running W. by S. and found just south of the west end of the Croy fault, is the only known indication of its further extension until, ¼ mile W. of Twechar, a dyke is again met in the workings, and runs W. and afterwards W. by N. to Burnfoot. Surface outcrops indicate the further course of the dyke south of Antermony Loch till it crosses the railway at Milton, whence it can be traced by quarry openings and in underground workings for two miles further west into the South Brae of Campsie.

In this part of its course, west of Milton, the dyke has curved away in a marked manner to the south along the Queenzieburn fault. Further west, however, on Craigmaddie Muir, an east-and-west quartz-dolerite dyke is found in the position which the Milton dyke would have occupied but for this deflexion ; it is therefore not unlikely the true continuation of the latter, which would then seem to be later than this part at least of the fault. To the west this dyke has been followed for some miles into the lavas of the Kilpatrick Hills.

The East Board Dyke.—The most southerly of the Kilsyth dykes has been proved for a distance of two miles in the Gartshore workings between Croy and St. Flanan, where it has in places a thickness of 190 ft. This dyke does not, however, appear anywhere at the surface, and its extension east of the railway is uncertain. C. B. C.

Dykes of the Cadder and Chryston area.—The dyke intrusions in the districts lying to the north and east of Glasgow include two important roughly parallel quartz-dolerite dykes which cross the area in an east-and-west direction, at a distance apart varying from 1000 yds. to a little over a mile. Where the dolerite has been intruded through carbonaceous rocks, the marginal portion is frequently altered into the white argillaceous rock known as "white trap" or "calm." Spheroidal or "bomb" weathering is a common phenomenon in these dolerites, and is most often met with in the central and coarser portion of the dyke.

There is no evidence to show that the intrusion of these east-and-west dykes is of earlier date than the main system of faulting of the region. On the other hand, the important Lenzie-Torphichen dyke appears in the Cadder ironstone workings to suffer no displacement by the Cadder fault, which has there a throw of 50 fms.

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[1] On the new one-inch Sheet 31 the presumed surface position of the dyke is indicated at, and west of, Kilsyth, while for some distance east of Kilsyth the position shown is that found in the coal workings.

The narrow E.N.E. dyke in the Shale Coal workings at Ashfield, also passes through a 75-fathom fault (the Garnkirk fault) with no apparent shift of position.

The Lenzie-Torphichen Dyke.—The northern of these two dykes forms the westward extension of an intrusion which has been traced —with a slight interruption of continuity near Lenzie—eastwards as far as Torphichen,[1] a distance of over twenty-five miles. Westwards there is no evidence that this dyke crosses the river Kelvin. Its position to the east of that river has been proved underground in the workings and bores of the Blackhill and Cadder ironstone fields, and the dolerite is first seen at the surface in an old quarry at the side of the canal one third of a mile west-south-west from Cadder Church. Between Boghead and Lenzie there is no evidence of its position either at or below the surface, but from Millersneuk the dyke forms a more or less conspicuous feature, with frequent rock exposures, that extends to the eastern margin of the sheet, a short distance west of Mollinburn.

About half-way between that village and Lenzie, an off-shoot of the dyke extending in a north-westerly direction towards Easter Bedcow is shown on the map; it appears to be portion of a sill, since it has not been met with in workings underneath.

The width of the intrusion varies from 20 yds. in the Blackhill workings to 80 yds. north of Gartferry Mains, but its average breadth over the greater part of its course may be taken as 40 to 50 yds. Between Lenzie and a point a little to the north-west of Gartferry Mains, the course of the dyke coincides with one of the great east-and-west lines of dislocation. Interesting evidence on this point is seen at the bridge by which the road from Lenzie to Mollinburn crosses the Garngaber Mineral Railway, near Wester Muckcroft. On the north side of the bridge, dark blaes and a thin coal, followed by blaes, fireclay and a thin bed of sandstone, are tilted up vertically against the wall of the dyke, while on the south side the latter is in contact with nearly horizontal beds of slightly indurated sandstone. The marginal portion of the dyke has been altered into white trap on either side, for a distance of 8 or 9 ft. inwards from the wall of the intrusion. In the case of the southern margin, next the sandstone, it is probable that the alteration is due to carbonaceous beds underlying the sandstone. At Bridgend junction, 300 yds. further to the south, the line is crossed by another dyke, which cannot, however, be traced far beyond the railway on either side. The sandstone in contact with this intrusion has suffered a considerable amount of alteration, and is converted into a close-grained quartzite. The marginal portion of this dyke is often full of small circular cavities containing zeolites and veins of calcite.

The Claddens Dyke.—The second main east-and-west dyke is first seen at the surface in a quarry 400 yds. S.W. of Kenmure House, Bishopbriggs, but its underground position is known to the west as far almost as Cawder Cuilt. Between Kenmure House and Brackenbrae it does not reach the surface, but is covered with several fathoms of burnt blaes. The dyke is well exposed a mile to the east, where it crosses the North British Railway line at Myremailing, and again in the quarry immediately east of Claddens. The dolerite in this quarry is a hard, fine-grained, dark blue rock, used for setts and road metal. The dyke is here vertical, and its breadth 30 to 35 yds. Other exposures are found along the old mineral tramway line further to the east, and in the burn that flows into the partially drained loch at South Loch.

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[1] In Sheet 31.

At this point the dyke is intruded into the dark shales immediately above the Calmy Limestone, and its marginal portion is a white trap. The exact position of the dyke eastwards to beyond Auchinloch is obscured by drift, but it appears again in old quarries at Blacklands and Knockmilly, beyond which last locality there is no evidence of its continuance at the surface. It has, however, been proved by underground workings to extend still farther to the E.S.E. in the direction of Moodiesburn. No evidence has so far been obtained to connect this intrusion with the dyke exposed at Bedlay House, Chryston, a mile to the east-south-east of Knockmilly, and well seen in a quarry at the side of the railway at the Glasgow Road bridge. Here again the dolerite pierces at the surface rocks on the horizon of the Calmy Limestone, and the calcareous shales are indurated against the margin of white trap. From this point to the edge of the map the dyke is nowhere exposed, but further to the east it gives rise to a well-marked feature which can be followed for a long distance.

Minor Dykes.—One of the less important dykes of this district traverses the sandstones of Coltmuir, west of Bishopbriggs, in a north-east and south-west direction, and is visible at the south end of the disused Kenmure Quarry. It is at that point 9 ft. in width, and shows columnar structure, but is much decomposed. The dyke is represented on the original Survey as coincident with a small fault with downthrow to north-west.

Other small " gaws " or dykes of " whin " have been recorded in underground workings in different parts of the area, but there is no evidence as to the nature of the rock of which they are composed. One of these narrow dykes, running E.N.E. and W.S.W., was met with in the Upper Possil Ironstone and Shale Coal workings between Hillend and Ashfield, in the north-eastern suburbs of the City. The Shale Coal on either side was burnt in the direction of Ashfield. L. W. H.

(2 or 3) *The Milngavie Dolerite Sills.*—The dolerite sills of the Milngavie district are intruded into the upper part of the Calciferous Sandstone Series, and, to a less extent, into the lower part of the Lower Limestone Group. They approximate in position to the Hurlet sill of the Paisley district, and may possibly be continuations of the same intrusion. Petrographically, however, they are of singularly indeterminate character, and have, indeed, been classed by Dr. Tyrrell with the quartz-dolerites.[1] C. B. C., E. B. B.

The Milngavie sills have a very restricted surface distribution. They make a considerable show between two parallel east-and-west faults, the one south of Milngavie, the other north of Mugdock Reservoir, but scarcely extend at all beyond these faults. To the south the dolerite has been traced no further than Law Farm, and to the north it can only be recognized in a few thin leaves of " white trap " overlying the Hurlet Limestone.

The highest of these sills rests upon the Baldernock Limestone at North Bardowie, and includes a lower fossiliferous horizon at Baldernock Mill (p. 27). Three-quarters of a mile further north, at a waterfall known as the Linn, it invades the Hurlet Coal and Limestone, and, a little further up-stream, is itself overlain by black shales on a slightly higher horizon. In the Linn section, where it is seen in contact with the Hurlet Coal, it has split this seam into several parts and strongly baked it, while it has itself suffered alteration into white trap.

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[1] 'Geology and Petrology of the Intrusions of the Kilsyth-Croy District, Dumbartonshire,' *Geol. Mag.*, 1909, p. 305.

The lower sills of this group are well exposed on the two sides of Craigmaddie Reservoir. C. B. C.

A dolerite sheet has also been mapped in the lava group at Mugdock, but we have no definite evidence of its field-relations, while its microscopic characters leave us in doubt as to whether or no it belongs to the Milngavie group of intrusions. G. W. G.

(3a) *The Cathcart Teschenitic Sills.*—Two or three thin sills of teschenitic dolerite, some of which have been shown to contain nepheline, are exposed along the valley of the White Cart above Cathcart. They occur a short distance below the Index Limestone, and have been proved in various borings further to the west. One of these sills, intruded immediately beneath the limestone, forms a waterfall below Linn House. A sill of similar thickness forms the cliff on which Cathcart Castle stands, and is here cut off by a fault with upthrow to the south-west. E. M. A.

(3b) *Teschenite Sills of Glasgow.*—Among the most interesting points in the geology of Glasgow and its environs, are the teschenite sills which form the summit of the Necropolis Hill, and give rise to the varied features of crag and hollow seen in the neighbourhood of Gartcraig, Hogganfield and Milncroft.

At the western end of the Necropolis one of these sills is intruded into the highest beds of the Millstone Grit, and on the steep face that rises above the hollow of the vanished Molendinar Burn, the igneous rock is seen resting on the sandstones of that formation.

Eastwards through Dennistoun the sill passes up into the base of the Coal Measures, and on the Alexandra Parade is in contact with the dark fossiliferous shales referred to on p. 95.

The Necropolis sill has not been traced at the surface farther east than Meadowbank Street and Roebank Street, but is probably continuous beneath with the Gartcraig intrusion to be referred to later. The white trap found in the cutting at Burnbank is probably in connection with this underlying sheet of teschenite. The extent of the sill to the south and south-east, in the ground covered by the streets and houses of Dennistoun, is somewhat conjectural, and the overlying patch of altered sandstone, shown on the original survey map, is no longer visible.

The presence of an intrusion of teschenite beneath the superficial deposits of the Clyde valley to the west of High Street is proved by the occurrence of rock, closely similar in petrological character to that of the Necropolis, in the railway cutting immediately west of College Station on the North British Railway, and in various excavations made in the area between George Street, Montrose Street, Wilson Street and Miller Street.[1] There is no certain evidence as to its further extension to the west of Miller Street, but the journals of bores put down during the construction of the original Caledonian Railway bridge over the Clyde record the occurrence of "whinstone" at a depth of 88 ft. beneath sand and clay. The exact nature of the rock is however unknown, and it should be noted that in more recent borings at the present bridge to a depth of 95 ft., no igneous rock was encountered. L. W. H.

The teschenite of the Necropolis can at present be studied with advantage in the Firpark quarries on either side of Firpark Street, where the rock is wrought for setts and road-metal. In the quarry nearest to the Necropolis the fine-grained upper portion of the sill is succeeded below by a foot or so of felspathic teschenite with long blades of augite. These sometimes reach a length of 3 in., and in places are curved and branching. The rock beneath is mostly darker and more even in grain, though thin layers and patches of the felspathic type are not uncommon. Segregation veins rich in pink felspar run irregularly through this portion of the intrusion.

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[1] *See also* a paper by Mr. F. Mort, M.A., B.Sc., 'The Extension Westwards of the Necropolis Intrusion,' *Trans. Geol. Soc. Glasg.*, vol. xiii., pt. i., 1907, p. 19.

In the eastern quarry about 40 ft. of rock are seen in the face. The sole is a decomposed white trap, and rests upon slightly indurated shale. The rock is much broken up in parts, and affected by small faults. In this quarry there is distinct evidence of successive intrusions. At one point a fine-grained rock, apparently the main rock of the quarry, underlies a higher coarse-grained band, against which it is evidently chilled, and into which it sends irregular apophyses. Pink, felspathic, segregation veins are also well seen in this quarry. They usually occur in association with a fine-grained blue rock which, in places, sends apophyses into the normal teschenite but does not show definite chilled margins. The amount of the blue rock present varies from place to place, and the pink veins may occupy a central or marginal position with respect to it. L. W. H., E. B. B.

East of Alexandra Park the teschenite first reappears at the surface in the railway cutting north of Kennyhill Goods Station, where it is in contact on the one side with indurated shale and on the other with sandstone. The sill is now rising rapidly through the strata of the Coal Measures, and at Gartcraig House occupies a position somewhere about that of the Splint Coal. The southward dip of the sheet from Gartcraig must coincide very nearly with the slope of the ground, for the fine-grained vesicular top of the sill, seen in the old quarry, is also well exposed in the small stream 250 yds. N.N.E. of High Carntyne. Beyond this point it appears to plunge steeply downwards, since it was met with at 60 fms. in a bore immediately south of High Carntyne.

As the sill passes over the Blackhill anticline to the north, it divides into two leaves, separated by a strip of sedimentary rock that widens northwards towards Provanmill. It is probable that the hollow features on the golf course and in the policies of Gartcraig House are also due to thin partings of sediment. The top of the sill is exposed in the old quarry by the side of the road, close to the entrance-lodge of Gartcraig House, and the southward dip of the sheet is plainly evident. The upper portion is markedly fine-grained, close-jointed, and in places vesicular, the vesicles being arranged in even layers parallel to the surface. The interior of the intrusion is a teschenite of normal coarse doleritic texture.

The face of the Orchard Quarry, a short distance to the east, presents a curiously stratified appearance. A rude system of columnar joints is intercepted by two remarkably persistent bands which have weathered out along the face like thin sedimentary beds. No chilled margins could be detected within the mass, and it is probable that the pseudo-stratification is of the same type as that described in the Milncroft Quarry in an ensuing paragraph.

The face of the Gartcraig Quarry shows about 40 ft. of teschenite resting upon slightly indurated shale, but this cannot be regarded as the entire thickness of the sills, as the original chilled top is not exposed. Indeed, the highest portion seen in this quarry is coarser than any other band, but has the spotted appearance characteristic of part of the sub-marginal zone at Milncroft.

On the northern limb of the anticline the two branches of the intrusion are each from 10 to 12 ft. in thickness. The rock is exposed in several old quarries about Hogganfield, and has been worked for road-metal in an opening by the roadside at Provanmill House, where the base of the sill is a decomposed "white trap." L. W. H.

To the east of Gartcraig the teschenite forms isolated outcrops as far as Blairtummock. The principal sill lies a short distance above the Splint Coal or actually in that coal itself, and is traceable on this horizon in bores and pit sections over a large part of the area lying between the outcrops mentioned above and the North British Railway to the south. At Provan Hall and Cardowan, however, the sill occupies a position even higher than that of the Main Coal, while in the south, at Threestonehill and Greenfield, near Shettleston, it sinks as low as the Blackband. None of the bores or pit sections south of the railway show any "whin."

A very interesting exposure of the teschenite is furnished by the Milncroft Quarry. The fine-grained upper part of the intrusion, about 15 ft. thick, is well shown at the roadside. Beneath this comes a 2-foot layer of extremely coarse texture with conspicuous columnar crystals of augite, an inch in length. This passes down through a mottled zone of rather greater thickness, into an even-textured rock of doleritic appearance. In places the transition from the mottled to the even-textured rock is quite gradual, but in other cases the change is abrupt. The normal teschenite is exposed for about 30 or 40 ft., but the base is not seen. At one time a thin seam of micaceous soft black rock was encountered well down in the quarry, and persisted for a distance of several yards, following the run of the other layers. It resembled the well-known picrites, but still retained a fair proportion of felspar. W. B. W.

(3c) *The Paisley Teschenitic Sills.*—Two separate sills, both confined to the Lower Limestone Group, are found in the neighbourhood of Paisley.[1] The larger of these—the Hurlet Sill—persistently follows the Hurlet Seam, and extends from Old Crookston, near Hurlet, northwards to the River Clyde. The smaller intrusion—the Hosie Sill—occupies a higher position in the series between the Blackhall and Main Hosie Limestones, and extends from Rosshill on the White Cart, to Bankhead, north of the Clyde. The area occupied by these sills at the surface is rather limited, and their extension, both above and below ground, has been mainly ascertained through boring evidence. The Paisley sills vary in character from teschenitic olivine-dolerite to teschenite and theralite.

The Hurlet Sill.—A poor exposure of this intrusion can be seen east of Old Crookston Farm, while, a few years ago, a complete section, showing its relations to the coal and limestone of the Hurlet Seam, was laid bare in the foundations of the new poorhouse close by (*see* p. 36). Very fine sections of all these strata are displayed to the east of Paisley, both in the Arkleston railway cutting, and in an old quarry by the White Cart, half a mile east of Blackhall.[2]

The Barshaw theralite, which is exposed in an old quarry above the Paisley road at Barshaw appears to form part of the Hurlet sill, judging from its dip and from the depth at which the Blackhall Limestone is met with in bores further to the east. The basic igneous rock upon which Elderslie House is built is also probably part of the same intrusion.

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[1] Paisley lies just beyond the western limit of the map.

[2] Summary of Progress for 1905, *Mem. Geol. Surv.*, 1906, pp. 125, 126. P. Macnair, *Trans. Geol. Soc. Glasg.*, vol. xiii, part i., 1907, pp. 58-60.

The sill was found to be 9 fms. thick in a bore near South Cardonald, but increases northwards, reaching 20 fms. in a deep bore at Shieldhall Co-operative Works. It was also met with in bores further down the river near Shiels.

The Hosie Sill.—This small intrusion, 4 to 5 fms. in thickness, is probably an offshoot from the larger Hurlet sill. It extends over much the same area, as far as the districts west of Glasgow are concerned, the two sills being, as a rule, at least 20 fms. apart.

The Hosie sill is nowhere exposed at the surface south of the Clyde, but has been met with in several bores between Ralston and North Cardonald, about the position of the Blackhall Limestone. On the banks of the Clyde, in the deep bore at Shieldhall Co-operative Works, it occurs at a somewhat lower horizon, only 9 fms. above the Hurlet sill. Further north it rises higher in the strata, and was found in a bore at Knightswood, close to the Main Hosie Limestone.

The Whiteinch dolerite,[1] the quarrying of which led to the discovery of the famous "fossil forest" (*see* p. 122) at the Victoria Park, is a part of the Hosie sill. The evidence of certain bores for ironstone, put down in the vicinity many years ago, and the occurrence of thick sandstone strata in the quarry, indicate that the sill is here either about the position of the Main Hosie Limestone, or perhaps rather higher, and just above the Johnstone Clayband.

Further to the west, at Bankhead and at Blawarthill cross-roads, the sill was found lower down in the Blackhall Limestone position. There is evidence that the well-known "Elderslie Rock" (which should not be confused with that on which Elderslie House is built), encountered close by in the river bed, is intruded at about the same horizon (*see* p. 201). R. G. C.

(4) *West-North-West Dolerite Dykes.*—It is believed that the W.N.W. dykes are of Tertiary age, like the north-west dykes which are so common a little further west along the shores of the Firth of Clyde, but they are in a greatly decomposed condition, so that their original petrological characters cannot be readily ascertained. Four of them are exposed in the North Calder River, between Calderbank and the east margin of the map, and another is seen close to a quarry 120 yds. south-west of Bredisholm Pit No. 3. The dyke which is furthest north-east makes little nicks in a massive sandstone on each side of the river about two-thirds of a mile E.N.E. of Newlands. It is only 15 in. thick and inclines steeply north-east. In the Lower Drumgray workings, about 760 ft. below the surface, the breadth is 3 ft. and the position is about 140 ft. further north-east, so that the general inclination must be rather less than 79°. This dyke has been traced in the mines for a considerable distance further north-west, with an average direction of about 32° north of west. It is accompanied on the south-west side by two subparallel dykes which are seen in the Calder about a mile north-east of Newlands. One is 4 or 5 ft. broad, and the other 2 ft., the latter being accompanied by a crush-plane inclining north-east.

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[1] *See* J. Young and D. C. Glen, 'Notes on a section of Carboniferous Strata . . . in the old whinstone quarry, Victoria Park,' *Trans. Geol. Soc. Glasg.*, vol. viii., 1888, p. 227. F. Rutley, referred to *infra*, p. 173. P. Macnair, 'The Intrusive Dolerites in the Neighbourhood of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part i., 1907, pp. 60-61.

The distance between the surface positions of the outermost of the three dykes in this locality is about 400 ft., but in the workings of the Splint and Virgin Seams, near Rhindmuir, a mile and a half further north-west, the distance is reduced to half this figure.

The Calder section, a third of a mile north-west of Newlands, shows a thin decomposed W.N.W. dyke at each side of the stream. One the south side the breadth is about 2 ft. In the Lower Drumgray workings the position is 200 ft. further north, which implies a general inclination in this direction of rather more than 75°. The dyke which runs about a quarter of a mile south of the last mentioned has only been observed at the surface in one place, close to the freestone quarry, 120 yds. south-west of Bredisholm Pit No. 3. It is inclined steeply towards the north and is somewhat crushed on the south side. In the Lower Drumgray workings, at a depth of more than 1000 ft., it lies 240 ft. further north, is 4 ft. broad, and in the condition of white trap, as narrow dolerite dykes nearly always are where they traverse carbonaceous beds. In the Ell workings the dyke is also accompanied by this fault, and the coal for 4 or 5 ft. off the dyke is burnt into a spongy coke (12697) which is so impregnated with carbonate that it cannot be used. The carbonates occur in small cellular cavities, and also form thin laminæ between the sides of the narrow columns, which have been formed in the coal at right angles to the side of the dyke.

Further west, in the Lower Drumgray workings of Ellismuir Pit No. 3, this dyke is still accompanied by a fault, with a throw of 10 ft. down to the north. The middle of the dyke is crushed approximately parallel to its direction, but a little further south certain thin squirts of the intrusive rock seem to have followed some earlier crush-planes, also strking north-west, and to have escaped subsequent crushing. The freshest specimen that could be got from the workings is still much decomposed. It is an olivine-dolerite (12695). C. T. C.

Several of the coalfields between Newton and the Hamilton Palace Colliery, near Bothwellhaugh, are traversed by W.N.W. dykes of dolerite, varying in breadth from a few inches up to several feet. These dykes appear to be later than the fault movements, and in the Newton field one of them occupies a line of fault. It is found that the amount of coal burnt and rendered useless on either side of these intrusions is in direct proportion to the breadth of the dyke. J. S. G. W.

III. Petrology of the Igneous Rocks.

INTRODUCTION.

The Glasgow district supplied many of the illustrations by which Allport,[1] in his classical paper, established the essential identity of Carboniferous and Tertiary dolerites. Some at any rate of the local rocks cited by this author, including various lavas and the Dunglass plug (Fig. 6, p. 143), are undoubtedly of Carboniferous age, and his contention, which was in agreement with the practice already adopted by Sir A. Geikie,[2] has by this time met with general acceptance.

Among the intrusions of more doubtful age, included by Allport with the Carboniferous dolerites, are the sills reaching east from Glasgow City, which, on account of their richness in analcite, have now come to be known as teschenites. This name was first employed in Scottish petrology by Sir Jethro Teall,[1] who introduced it from Continental literature as an alternative title for the analcite-dolerite of Car Craig in the Firth of Forth, while he referred to the Glasgow rock as a "micaceous dolerite of the Car Craig type." Allport had very naturally mistaken the abundant isotropic analcite in the Glasgow intrusion for glass.

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[1] 'On the Microscopic Structure and Composition of British Carboniferous Dolerites,' *Quart. Journ. Geol. Soc.*, vol. xxx., 1874, p. 529.

[2] *Cf.* 'On the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth,' *Trans. Roy. Soc. Edin.*, vol. xxix., 1880, p. 492.

Since Sir Jethro Teall wrote, Mr. Mort[2] and Prof. Peter Macnair[3] have both described the Glasgow sills. Prof. Macnair has also demonstrated the teschenitic affinities of the Cathcart sills to the south-west, and, in accordance with a view which has found increasing support of late years, he suggests that the analcite in this latter case may be of primary origin. The point is perhaps not definitely proved, but the present writer regards the major portion of the analcite, not only in the Cathcart teschenite but also in many other rocks of the Glasgow district, as primary in origin—the word "primary" being employed in a broad sense to include the results of "juvenile" decompositions, which run their course before the truly igneous history of the cooling rock has come to an end.[4] At any rate the clear analcite of the teschenites has not resulted from weathering of nepheline *in situ*, for nepheline, both fresh and decomposed, occurs in the Cathcart teschenite, and its pseudomorphs are quite distinctive.

Another nepheline-bearing rock is the Lennoxtown essexite, described in the first instance by Allport, although he naturally did not distinguish it specifically from the other "dolerites" of the district. This Lennoxtown rock is mainly noteworthy for its close resemblance to certain well-known essexites described by Brögger from Christiania. An ultrabasic nepheline-bearing rock, the Barshaw theralite or bekinkinite, may also be mentioned here as one of the treasures of Glasgow petrology. The district, in short, is full of petrographical material of the first importance, and from results already obtained by Sir A. Geikie,[5] Dr. Falconer,[6] Prof. Macnair,[7] Dr. Tyrrell,[8] and Mr. Boyle,[9] it is known that interest is likely to quicken rather than flag, as the igneous rocks of Ayrshire to the west come to be examined.[10]

To Sir Jethro Teall[11] again is due the first description of micropegmatite and hypersthene from the quartz-dolerites of Scotland, although the recognition of the primary nature of some of the quartz of the

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[1] 'British Petrography,' 1888, Plate xxii., Fig. 1.

[2] 'The Extension Westwards of the Necropolis Intrusion,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part i., 1907, p. 19.

[3] 'The Intrusive Dolerites in the Neighbourhood of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part i., 1907, p. 56.

[4] Dr. G. W. Tyrrell, who has an extensive knowledge of the teschenites of Western Scotland, also advocates the primary nature of the analcite occurring in these rocks, *Trans. Geol. Soc. Glasg.*, vol. xiii., part iii., 1909, p. 307.

[5] 'Ancient Volcanoes of Great Britain,' 1897, vol. ii., p. 67.

[6] 'The Geology of Ardrossan,' *Trans. Roy. Soc. Edin.*, vol. xlv., 1908 (issued separately, 1907), p. 601.

[7] *Loc. cit.*, p. 83.

[8] *Nature*, 1909, vol. lxxxii., p. 188, and 'The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part iii., 1909, p. 298.

[9] 'The Occurrence of Ultra-Basic Rocks in the Igneous Intrusions of the Lugar and Cumnock District,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part ii., 1908, p. 202.

[10] Since the first edition of this memoir, Dr. Tyrrell has published several important papers. Reference should be made to the Bibliography that accompanies his paper on 'Classification and Age of the Analcite-bearing Igneous Rocks of Scotland,' *Geol. Mag.*, 1923, p. 249; also to Dr. F. Walker's 'Notes on the Classification of Scottish and Moravian Teschenites,' *Geol. Mag.*, 1923, p. 242.

[11] *Loc. cit.*, p. 190.

Stirling sill near Denny we owe to Sir A. Geikie.[1] Allport had already stated that specimens from the Kilsyth sills "are almost indistinguishable from those collected at Ratho and West Craig, near Edinburgh," and Sir Jethro Teall was able to extend this statement, pointing out that while the Kilsyth and Stirling sills resemble the Ratho sill, the latter, "in the character of the augite, as well as in the presence of micropegmatite and a rhombic pyroxene," resembles certain portions of the Whin Sill of the North of England, which he himself had carefully studied.

The Kilsyth sills have recently been made the subject of an interesting paper by Dr. Tyrrell,[2] with an analysis by Mr. Macdonald. Incidentally Dr. Tyrrell summarizes the abundant literature dealing with the quartz-dolerites, both British and foreign, and he also suggests that the quartz-dolerites represent the saturation point of a normal doleritic magma with siliceous material, which has been assimilated in deep seated reservoirs from surrounding country rock. It is to be hoped that more light will be thrown, in the future, on the phenomena of abysmal assimilation, but Dr. Tyrrell's suggestion, as it stands at present, involves many uncertainties, such as the conception of a "normal" dolerite magma. In subsequent pages a different aspect of these interesting rocks will be dealt with, and it will be pointed out that they, at any rate, furnish useful and suggestive object lessons in magmatic differentiation after intrusion.

While the mesostasis of the coarser quartz-dolerite sills and east-and-west dykes is micropegmatite, glass is found in many less crystalline examples, but almost invariably in a much decomposed condition. Fortunately, however, a typical east-and-west dyke, opened up in a quarry a quarter of a mile north-west of Kinkell, provides specimens with glassy variolitic base in perfect preservation. This occurrence was discovered and described by Mr. Veitch Lothian.[3]

Sir Jethro Teall[4] suggested, after discussing the various types of intrusions referred to above, that the "minute peculiarities of structure and composition" observed might in the future prove of local value in dating the several intrusions, without invalidating Allport's more general proposition. From what has been said in the preceding part of this chapter it is clear that Sir Jethro Teall's hope has already been justified, but that at the same time much work remains to be done along this promising line of inquiry.[5]

Most of the lavas of the Glasgow district are basaltic in character and fall into place in the classification elaborated by Dr. Hatch[6] and Professor Watts.[7] One of the main features of the Campsie Fells is the great profusion of the Jedburgh type of basalt, and it has been possible to link this type with the mugearites, the presence of which in the Scottish Carboniferous igneous rocks was first detected by Mr. Barrow.[8]

Intermediate and acid rocks are well represented by intrusions and tuffs in and about the Meikle Bin vent of the Campsie Fells, and, as we have pointed out already, they have been described by Sir Archibald Geikie and Mr. Lothian. They consist for the most part of trachytes and felsites, while the Fintry intrusion (Fig. 6, p. 143) proves to be a trachytic phonolite with conspicuous ægirine and fresh nepheline. It is most unfortunate that all the felsites examined so far are much decomposed.

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[1] *Loc. cit.* p. 490.

[2] 'Geology and Petrology of the Intrusions of the Kilsyth-Croy District, Dumbartonshire,' *Geol. Mag.*, 1909, p. 299.

[3] 'The Petrology of the Kilsyth Hills,' printed privately, 1902, p. 15.

[4] *Loc. cit.*, p. 187.

[5] *Cf.* G. W. Tyrrell, *Trans. Geol. Soc. Glasg.*, vol. xiii., part iii., 1909, p. 298.

[6] Quoted by Sir A. Geikie, 'Presidential Address,' *Quart. Journ. Geol. Soc.*, vol. xlviii., 1892, p. 129.

[7] Quoted by Sir A. Geikie, 'Ancient Volcanoes of Great Britain,' 1897, vol. i., p. 418.

[8] *Cf.* 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 123.

In preparing this petrological description of the igneous rocks of the Glasgow district, the writer has been very greatly indebted to Mr. E. G. Radley for ten complete analyses prepared specially for the memoir, and to Sir John Flett for much advice and assistance.

The main feature now established is, that, setting apart the quartz-dolerite intrusions and also the decomposed west-north-west dykes, all the igneous rocks, both lavas and intrusions, are referable to a magma of alkali character, bordering upon sub-alkali; for instance, the prevalent basic rocks of the district lie midway between the essexites and gabbros in composition, while the less extensively developed intermediate rocks[1] are alkali trachytes, with a few trachytic phonolites, but without any such associates as the nephelinitoid phonolites, so characteristic of the more extreme alkali magmas.

The importance of "half-way houses," as one may term them, in petrological classification was emphasized by Brögger when he reorganized the monzonite group in the interval between the syenites and the diorites; the half-way house in the present instance, lying between the essexites and the gabbros, is one to which increasing importance is likely to be attached before many years have passed.

The Glasgow area agrees closely in its petrographical features with the recently described districts of Edinburgh and East Lothian,[2] so that it has been possible to treat certain matters very briefly. The petrology of the Kilpatrick Hills, it should be stated, was largely worked out by Mr. Grabham before he left the Survey, and his results have been incorporated in the body of this description. A point of special interest discovered by Mr. Grabham, and described in a conjoint paper with the writer,[3] may be dealt with at this juncture.

In a few cases in the Cathkin Hills and in many instances in the Campsie Fells and Kilpatrick Hills (*e.g.* on the hilltop above Lennoxtown and 150 yds. north-east from Carbeth), the basic plagioclase felspars of the lavas have been replaced more or less completely by albite. So thorough is the change that there seems no room for doubt that in many examples there has been an important introduction of soda into the altered felspars. It is also found that, in any rock which shows the change at all, the more basic felspars are the more liable to albitization, and, in any particular felspar, the more basic portions are picked out first. On the other hand, the basic felspars of the thoroughly basic lavas escape, while the less basic felspars of the Markle basalts and the mugearites are very frequently attacked, so that it is clear that albitization depends not only upon the nature of the felspar in any particular instance, but also upon the nature of the lava which encloses the felspar. It appears probable, therefore, that albitization is in some cases a "juvenile" change in which the residual magma of the almost consolidated rock plays an all-important *rôle.*[1]

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[1] In 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, pp. 104, 123, the term intermediate was unfortunately applied to the trachybasalts (trachydolerites *see* footnote p. 000), especially the mugearites which in some features resemble andesites; but the trachybasalts are basic rocks running parallel with the basalts just as the essexites run parallel with the gabbros.

[2] J. S. Flett in 'The Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, Chap. XV., and E. B. Bailey in 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, Chap. X.

[3] 'Albitization of Basic Plagioclase Felspars,' *Geol. Mag.*, 1909, p. 250.

Albitization had already been described by Duparc and Pearce, and a related, though perhaps not identical phenomenon, by Termier, and these authors are quoted in the paper referred to above. A simultaneous account of the phenomenon has also been published by Niethammer,[2] who very truly remarks that many rocks described as keratophyres must be regarded as albitized porphyrites, etc. Niethammer does not think that, in the cases described by him from Sumatra, there has been introduction of soda, but merely a separation of the lime as zoisite in the form of minute inclusions which render the albite turbid.

Another point of general interest is furnished by the nepheline already referred to as occurring in some of the basic rocks of this district. The mineral has been observed fresh in the Lennoxtown and Crawfordjohn (Lanarkshire) essexites, in the Cathcart teschenite and in one slide from the Barshaw theralite. In the three former rocks, in which observations could be taken, its refractive indices were found by comparison with oils to be about 1·526 and 1·522. These low values correspond with what was obtained for the "nepheline x" of the Chesters quarry and Limplum nepheline basalts of East Lothian.[3]

The values for nepheline from Arkansas are 1·547 and 1·542, and those for the same mineral from Somma are 1·542 and 1·538. This shows that the indices vary considerably, and lately we found that nepheline in a tinguaite from Cargill, New Zealand, presented to the Geological Survey by Professor Marshall, has refractive indices about 1·534 and 1·530. These values are not quite so low as the Scotch numbers, but they strongly support the view that "nepheline x" is a variety of nepheline—probably with some minor chemical peculiarity—and this view has been adopted in the sequel.

The refractive indices of the nepheline of the Fintry phonolite, it may be noted, are quite normal, being approximately the same as those of the Somma specimens of the mineral.

One last point remains before turning to the detailed descriptions of the various rock types. In many of the more coarsely crystalline basic intrusions of Central Scotland, iron ore is abundant in large partially open crystals. These consist of an intergrowth of magnetite and ilmenite similar to those described by Cathrein[4] from Greimer in Zemmgrund. The open skeleton form of ilmenite can sometimes be directly observed in thin slices, but becomes much more evident after immersion of the slice for half an hour in cold strong hydrochloric acid (13311a),[5] when the attendant magnetite is dissolved away. Again, if one of the basic rocks be powdered the iron ore can be picked out with a magnet, but after treatment with acid for a couple of days, the residue ceases to be magnetic and proves on inspection to be deep brown ilmenite.

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[1] Albitization may also result through independent solfataric action. *Cf.* Albitization in Index of 'Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban,' *Mem. Geol. Surv.*, 1924.

[2] 'Die Erupivgesteine von Loh oelo auf Java,' *Tschermaks Min. Petr. Mittheilungen*, vol. xxviii., 1909, p. 218.

[3] 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 110.

[4] *Zeit. Kryst*, xii., 1887, p. 40.

[5] Numbers in brackets refer to slices in Geological Survey Collection.

ESSEXITE, TESCHENITE, ETC.

The Lennoxtown Essexite.—In the hand the Lennoxtown essexite (p. 152) presents the appearance of a fine-grained gabbro or coarse dolerite, in which black augite and white felspar can clearly be distinguished. A beautiful porphyritic type[1] is exposed by the roadside near the limestone workings, containing augite crystals measuring a quarter of an inch across. This porphyritic variety is all but identical in appearance with the well-known Crawfordjohn rock of Lanarkshire and the Branberget essexite of Christiania. Further up the road from the lime works the Lennoxtown essexite carries conspicuous flakes of biotite, and has weathered to a crumbling mass crossed by one or two narrow aplitic dykes.

A good general description of the microscopical characters of the rock (" south slope of the Campsie Hills near Skilliangow ") has already been given by Allport,[2] who recognized its more abundant constituents.

Purple augite, olivine and plagioclase felspar, in roughly equal proportions, make up the bulk of the rock. Flakes of red-brown biotite, grains of titaniferous magnetite (proved in this rock to be an intergrowth), long needles of apatite and interstitial patches of analcite are also conspicuous, while orthoclase and nepheline can be found by searching.

The olivine on the whole crystallized first, though very occasionally it includes minute crystals of iron ore. It occurs in irregular grains of considerable size, less frequently in well-formed crystals. It is remarkably fresh.

The purple pleochroic augite varies not a little in its development. The larger individuals show a faint zonal structure in the arrangement of their small inclusions of iron ore and felspar, and also in their behaviour between crossed nicols. They are occasionally idiomorphic, but more often hypidiomorphic, their margins being moulded upon the surrounding felspars. Smaller crystals are usually quite ophitic. Many of the augite crystals are grown about a core of olivine, and this accounts for their dull, lack-lustre appearance in hand specimens. Twinning is sometimes observed.

The plagioclase felspars give lath-shaped sections which do not show any marked zonal structure. The majority of them must be thoroughly basic, and bytownite has been recognized.

Titaniferous magnetite is abundant. The crystals attained their full development at a late stage, being frequently moulded on the felspar laths. Large individuals are often seen enclosed in the outer rim of the augite crystals, but never in their interior.

The red-brown biotite is also of late consolidation, and is for the most part attached to the iron ore and olivine grains. As a rule it is fairly conspicuous without being abundant. In the mica-rich type (13312), however, it ranks in importance alongside of the olivine and augite. Here especially it shows a tendency to the ragged poecilitic growth common in basic rocks, *e.g.*, kentallenite.[3]

Apatite is relatively abundant and began to crystallize before the augite ceased. Some of the needles are over two millimetres in length.

Orthoclase occurs for the most part as an outer zone grown upon the plagioclase felspars. It has good boundaries against the analcite patches. It is a very minor constituent.

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[1] [Dr.] John Young, 'On the Occurrence of Pyroxene or Augite in Large Crystals, in two Localities in Western Scotland,' *Trans. Geol. Soc. Glasg.*, vol. x., part i., 1895, p. 13.

[2] *Loc. cit.*, p. 559. Skilliangow = Sculliongour.

[3] J. J. H. Teall, Annual Report for 1896, *Mem. Geol. Surv.*, 1897, p. 22.

The nepheline generally occurs as an interstitial cement moulded upon the felspars, orthoclase included. Sometimes, however, it shows crystal boundaries against the felspars, and is always idiomorphic where it meets analcite. The nepheline is partly decomposed to micaceous products which accentuate its cleavage. On staining (13311a) it is evident that the nepheline is more abundant than appears at first sight. The finding of this mineral in the Lennoxtown rock is quite in accord with its discovery by Lacroix[1] in the Crawfordjohn rock, for the two are identical, save that the former is the richer in olivine.

Clear analcite fills in small angular cavities between the other constituents. It certainly has not replaced nepheline *in situ*, for the latter, where decomposed, has yielded characteristic pseudomorphs. In the variety rich in biotite (13312) the analcite increases somewhat in importance. In the similar but more felspathic "aplitic" veins (13313) the analcite is distinctly more abundant and includes certain dusty polyhedral micaceous pseudomorphs suggesting the original presence of sodalite.

	A.	I.	II.	B.	C.	D.	III.
SiO_2	43·65	45·03	47·03	50·50	48·61	48·77	47·26
TiO_2	4·00	2·30	2·64	1·91	—	—	2·38
ZrO_2	—	—	0·03	—		—	—
Al_2O_3	11·48	14·82	15·36	17·71	—	—	13·03
Cr_2O_3	—	—	0·02	—	—	—	—
V_2O_3	—	—	0·03	—	—	–	—
Fe_2O_3	6·32	2·77	3·38	5·41	—	—	2·89
FeO	8·00	8·81	7·35	4·02	—	—	7·82
MnO	trace	0·37	0·14	—	—	—	0·23
(Co,Ni)O	—	0·05	trace	—	—	—	0·03
MgO	7·92	7·79	5·10	3·33	—	—	6·08
CaO	14·00	9·83	8·47	7·91	—	—	10·44
SrO	—	—	0·05	–	—	—	—
BaO	–	nt. fd.	0·08	—	—	—	0·08
Na_2O	2·28	4·33	4·32	5·52	4·30	2·45	3·92
K_2O	1·51	1·51	3·00	3·02	2·27	0·57	2·32
Li_2O	—	? trace	nt. fd.	—	—	—	trace
H_2O above 105° C.. .	1·00	1·71	2·60	0·45	—	—	2·51
H_2O at 105° C. . .		0·24	0·22		—	—	0·29
P_2O_5	trace	0·58	0·73	0·92	—	—	0·53
CO_2	trace	0·22	nt. fd.	—	—	—	0·24
Cl	—	—	0·04	—	—	—	—
S	—	—	0·08	—	–	–	—
FeS_2	—	0·15	—	—	—	—	nt. fd.
	100·16	100·51	100·67	100·70	—	—	100·05

A. Essexite, Brandberget, Norway. Anal L. Schmelck; quoted from Brögger, *Quart. Journ. Geol. Soc.*, vol. l., 1894, p. 19.

I. Essexite, Lennoxtown (13311). Anal. E. G. Radley.

II. Essexite, Island of Craigleith. Anal. W. Pollard; quoted from 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 117.

B. Essexite, Rongstock, Bohemia. Anal. R. Pfokt; quoted from Hibsch, *Tsch. Min. Pet. Mitt.*, 1896, xv, p. 487.

C. Average of twenty essexite analyses quoted by Rosenbusch, 'Elemente der Gesteinslehre,' 1910, p. 196.

D. Average of eighteen gabbro analyses (including three norites) quoted by Rosenbusch, *loc. cit.* p. 180.

III. Nepheline-teschenite, quarry west side of Cathcart Castle (13650). Anal. E. G. Radley.

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[1] *Comptes Rendus*, 1900, cxxx., p. 1273; for a recent description, *see* A. Scott, 'The Crawfordjohn Essexite and Associated Rocks,' *Geol. Mag.*, 1915, p. 455.

The Lennoxtown essexite has much in common with the olivine-gabbros, but is distinguished by the presence of accessory nepheline, analcite and orthoclase, and by the rich purple colour of its augite.

It is, in fact, an alkali gabbro, and this is clearly demonstrated by Mr. Radley's analysis. It is most unusual for what may be termed a normal gabbro, with less than 50 per cent. of silica, to have as much as 4 per cent. of total alkalies, whereas the Lennoxtown rock, with 45 per cent. silica, has 5·84 per cent. of alkalies.

There are three varieties of alkali gabbro to which the Lennoxtown rock might be referred—namely the theralites, the teschenites and the essexites. The two former may be passed over on negative grounds, for there is scarcely sufficient nepheline to justify the inclusion of the rock among the theralites, or enough analcite to place it with the teschenites. On the other hand, while it is not a typical essexite, for it is poor in orthoclase, it strongly resembles Brögger's Christiania essexites, especially that of Branberget. These latter were first described by Brögger[1] under the name of olivine-gabbro-diabase, but were subsequently[2] referred to the olivine-monzonites, and finally[3] to the essexites; they are in a sense intermediate between the gabbros and the more typical essexites.

The name essexite was introduced by Sears[4] to designate a particular type of basic alkali-rich rock occurring at Salem Neck, Essex County, Massachusetts. One of the distinguishing features of his description is the absence of olivine[5], but Rosenbusch[6], who followed with a more detailed account of the rock, included local varieties containing this mineral. In fact he expanded[7] the significance of the term essexite, making it a group title equivalent in importance to that of granite or diorite, and he admitted a corresponding laxity into its definition, which at present runs as follows:—[8]

The essexite group includes hypidiomorphic quartz-free plagioclase-pyroxene rocks, with variable amount of orthoclase and felspathoids, and of barkevicitic hornblende and biotite.

In applying this definition Rosenbusch does not insist at all upon the presence of felspathoids or barkevicite, and also recognizes a subdivision of the group rich in olivine. His inclusion of the Christiania examples shows, too, that the "variable" amount of orthoclase need not exceed that occurring in the Lennoxtown rock, and we accordingly class the latter as an olivine-rich essexite. It must be mentioned, however, that Lacroix[9] has described the very similar Crawfordjohn intrusion as "an olivine-teschenite passing in structure to tephrite." This difference of nomenclature emphasizes the intermediate position occupied by the Lennoxtown rock—an essexite, with teschenitic and theralitic affinities, at the same time nor very far removed from the normal gabbro stock.

The Cathcart Nepheline-Teschenites (p. 160).—The petrographical character of the Cathcart sill was first investigated by Prof. Macnair,[10] who described a specimen, rich in brown hornblende, as recalling the characters of the well-known teschenites of Hohenegger.

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[1] 'The Basic Eruptive Rocks of Gran,' *Quart. Journ. Geol. Soc.*, vol. l., 1894, p. 19

[2] 'Die Eruptivgesteine des Kristianiagebietes,' 1895, ii. p. 43.

[3] H. Rosenbusch, 'Mikroskopische Physiographie,' 1896, ii., p. 250.

[4] *Bull. Essex Inst.*, 1891, xxiii., p. 146.

[5] *See also* H. S. Washington, 'The Petrographical Province of Essex Co., Massachusetts,' *Journ. Geol.*, 1899, vol. vii., p. 53.

[6] *Op. cit.*, 1896, ii., p. 248.

[7] 'Elemente der Gesteinslehre,' 1898, p. 171.

[8] 'Mik. Phys.,' 1907, ii., p. 391.

[9] *Loc. cit.*

[10] *Loc. cit.*, pp. 81-82.

Hornblende, in notable quantity, occurs in only one of the Geological Survey slides (13652), a decomposed specimen from the old quarry on the east bank of the river west of Cathcart Castle. It is grown about the augite, and in some cases at all events shows idiomorphic boundaries.

In the other specimens the place of hornblende is for the most part taken by chestnut-brown biotite, a much commoner mineral in the basic intrusions of the Central Valley of Scotland. These biotite-bearing rocks of Cathcart include nepheline-teschenite, represented by a beautifully fresh specimen from the quarry already mentioned (13650 and Analysis III., p. 170), and closely related olivine-dolerite (13649), from the linn half a mile south of Cathcart Castle. The difference between the two consists in the presence of a fair proportion of nepheline and analcite in the former, and the almost complete absence of these minerals from the latter.

The resemblance between the Cathcart rocks and the Lennoxtown essexite is so close that a detailed description is unnecessary. They are finer in texture, however, and, while they carry much less olivine, they are generally richer in biotite.

Pale purple-brown augite and basic plagioclase felspar are the most important constituents; olivine, occasionally fresh (13650), biotite, titaniferous magnetite and, in some cases, nepheline and analcite, are important accessories, while apatite is conspicuous, and orthoclase may be detected on search.

The structure is hypidiomorphic with an ill-marked porphyritic tendency on the part of the augite. The analcite sometimes occurs in rather large angular interspaces, and where this is the case the rock may be classed as a teschenite; like the Lennoxtown essexite, however, it occupies an intermediate position between the teschenites, essexites and theralites. The analysis by Mr. Radley (p. 170) clearly vindicates its inclusion in the alkali gabbro suite. In texture it is doleritic, and accordingly it might be classed as a coarse basanite.

The Glasgow Teschenites (pp. 160-2).—The Glasgow teschenites are thoroughly characteristic augite-teschenites of a type well known in the Lothians and exemplified by the Car Craig teschenite of the Firth of Forth. The Necropolis rock, Glasgow, has been described successively by Allport,[1] Sir Jethro Teall[2] and Prof. Macnair.[3] Sir Jethro Teall was the first to point out its resemblance to the Car Craig rock, and compare the latter with the teschenites of the Continent.

The main constituents of the Glasgow teschenites are purple-brown zonal augite, basic plagioclase felspar and analcite. The felspar is almost always very much decomposed.

The structural relations of the augite and felspar vary between hypidiomorphic and ophitic. The analcite occurs, for the most part, as large crystals, or crystal groups, filling in the angles between the other minerals. The analcite patches are often exceedingly clear, but they appear to be liable to a decomposition inducing turbidity. It is difficult to regard this interstitial analcite as secondary, but it must be admitted that it sometimes encloses idiomorphic rosettes of serpentine (13328), and, on the hypothesis of the primary origin of the analcite, these latter require special explanation. Possibly serpentine has the power of actually growing in the heart of solid analcite,[1] or possible the decomposition of the olivine of the teschenites and the resulting formation of serpentine, may be included in the category of juvenile reactions. There is no indication of the former presence of nepheline in these teschenites, except in the pink veins to be described later.

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[1] *Loc. cit.*, p. 560.

[2] 'British Petrography,' 1888, p. 194.

[3] *Loc. cit.*, pp. 68, 79-80. An analysis of the Craigpark quarry rock at Dennistoun is quoted by Naismith in *Trans. Geol. Soc. Glasg.*, vol. vii., part i., 1883, p. 190.

Analcite also occurs replacing felspar crystals. In this situation it is obviously secondary, in one sense of the term, although it may still belong to the igneous portion of the rock's history.

Olivine has been fairly abundant and is now entirely represented by small sepentine pseudomorphs. Biotite is constantly present, often as small rather ragged flakes attached to the iron ores. It is very seldom abundant (13330).

Hornblende is rare, but can sometimes be detected as an original growth upon the augite crystals (8272).

Iron ores are represented by open skeletal growths of titaniferous magnetite. Apatite is a characteristic accessory, occurring in long needles.

The segregation veins of the Glasgow teschenites seem to be restricted to the vicinity of the Necropolis. They have been referred to in all earlier descriptions, where Allport recognizes their felspathic nature and their comparative richness in hornblende. This holds good in regard to the pink veins ; the blue veins, which so often flank the pink, uniting with the latter to form miniature "composite sills," are fine-grained olivine basalts rich in iron ores ; they show flow structure and are microporphyritic as regards their felspars ; in fact they greatly resemble the Jedburgh type of basalt to be described later, but differ rather in the idiomorphic tendency of their little augite crystals, and in containing an easily recognizable amount of biotite.

The pink veins (13831) are very interesting. Their most conspicuous element is brown hornblende in scattered idiomorphic needles. These lie in a felspathic base, which in part consists of large irregular zoned crystals of alkali felspar (? orthoclase), and in part of a variolitic meshwork of small indeterminate felspar needles. Nepheline has almost certainly been an original constituent, and is now represented by numerous yellowish pseudomorphs, which, though traversed by the hornblende needles, present typical square and hexagonal outlines to the felspars. Apatite and iron ores, often replaced by leucoxene, are rare ; olivine, augite[2] and, what is more surprising, biotite are absent (from the specimen examined) ; analcite occurs, but not in clear patches.

The Paisley Sills (pp. 162-3).—The Paisley sills are generally too decomposed for microscopic examination.[3] A specimen from Hurlet (13648) proves to be an ophitic dolerite with purple augite, abundant olivine and but little analcite ; it resembles somewhat the Galliston type[4] of Fife.

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[1] Analcite is completely replaced within the Pneumatolytic Limit of Mull, *see* 'Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban,' *Mem. Geol. Surv.*, 1924, p. 141.

[2] The figure given by Sir Jethro Teall, *loc. cit.*, Pl. xiii., Fig. 1, contains augite, but probably represents a junction between the teschenite containing augite, with a vein containing hornblende alone.

[3] *Cf.* F. Rutley, 'On Tachylyte from Victoria Park, Whiteinch, near Glasgow, with an Analysis of the Rock by P. Holland,' *Quart. Journ. Geol. Soc.*, vol. xlv., 1889, p. 626.

[4] Described by Dr. F. H. Hatch, quoted by Sir A. Geikie, 'Presidential Address.' *Quart. Journ. Geol. Soc.*, vol. xlviii., 1892, p. 130.

It is much to be regretted that so little is known of the main mass of the Paisley sills, for one quarry, near the road at Barshaw, has yielded a rock of quite exceptional interest, which will now be described.

The Barshaw Theralite or Bekinkinite.—This rock is only known from one quarry which is entirely excavated in it. It is obviously a special modification of the Paisley teschenite or dolerite.

In the hand specimen the theralite resembles an ordinary dark dolerite. Under the microscope, however, it presents a very striking appearance.

The bulk of the rock consists of purple zonal augite and brown hornblende in about equal proportions. The hornblende is as usual grown about the augite, but externally shows its normal faces. Olivine is more sparingly represented by well-formed pseudomorphs in serpentine. Iron ores are scarce and small, biotite is absent, apatite fairly abundant.

There is a little plagioclase felspar present, but most of the rather abundant matrix consists of secondary products, chlorite and clouded analcite. The latter differs greatly in appearance from the clear analcite of the teschenites, and one slide (12873) shows that, in part at least, it is derived from the decomposition of large allotriomorphic crystals of nepheline.

	I.	II.	III.	IV.	A.	B.	C
SiO_2 . . .	40·87	44·73	40·2	42·49	45·66	40·10	43·60
TiO_2 . . .	2·85	1·53	2·9	2·51	2·75	2·98	2·44
Al_2O_3 . . .	16·23	11·89	12·8	13·85	11·64	15·50	13·60
Cr_2O_3 . . .	—	0·05	—	—	—	—	—
V_2O_3 . . .	—	0·03	—	—	—	—	—
Fe_2O_3 . . .	1·31	4·85	4·0	2·59	3·57	6·35	3·95
FeO . . .	7·37	6·61	10·4	9·32	10·61	7·29	6·95
MnO . . .	0·64	0·41	—	0·29	—	—	—
(Co,Ni)O . .	0·06	0·03	—	0·09	—		—
MgO . . .	9·83	10·77	11·9	11·21	11·08	8·41	10·20
CaO . . .	11·13	7·69	10·4	9·76	9·11	12·40	12·10
BaO . . .	nt. fd.	0·03	—	0·04		—	—
Na_2O . . .	2·78	2·77	2·7	2·39	2·60	3·37	3·74
K_2O . . .	0·53	0·89	0·8	0·87	0·44	1·67	0·69
Li_2O . . .	? trace	? trace	—	nt. fd.	—		—
H_2O above 105° C.	4·28	4·15	3.4*	3·35	—	0·87*	2·75
H_2O at 105° C. .	1·35	3·49		0·47	—		
P_2O_5 . . .	0·52	0·46	—	0·61	0·26	1·28	0·43
CO_2 . . .	0·38	—	—	0·22	—	—	—
FeS_2 . . .	0·21	—	—	nt. fd.	—	—	—
S . . .	—	0·05	—	—	—	—	—
	100·34	100·43	99·5	100·06	97·72	100·22	100·45

* Loss on ignition.

I. Theralite or bekinkinite, Barshaw near Paisley (13314). Anal. E. G. Radley.

II. Blackburn picrite, West Lothian. Anal. W. Pollard; quoted from Flett *in* 'The Geology of the Neighbourhood of Edinburgh,' *Mem. Geol. Surv.*, 1910, p. 300.

III. Nepheline-basalt ('limburgite'), Chester's Quarry, East Lothian. Anal. J. H. Player; quoted from Hatch, *Trans. Roy. Soc. Edin.* (1892), vol. xxxvii., 1895, p. 116.

IV. Hillhouse type of basalt, Hillhouse Quarry, West Lothian (14075). Anal. E. G. Radley.

A. Pyroxenitic ijolite, N.W.-Kamm des Penikkavaara near Jivaara, Finland; quoted from Rosenbusch, 'Elemente der Gesteinslehre,' 1910, p. 210.

B. Bekinkinite ('ijolite'), Ambaliha, Madagascar. Quoted from Lacroix, 'Matériaux pour la Minéralogie de Madagascar,' *Nouv. Archives du Muséum* (4), i., Paris, 1902, p. 138.

C. Bekinkinite ('ijolite'), Bekinkina, Madagascar; quoted from Lacroix, *op. cit.*, 1903, ii., p. 229.

It is thus a theralite, according to Rosenbusch's definition of the latter. But Mr. Radley's analysis clearly shows that it differs in composition from previously described theralites, for the latter are less basic and distinctly richer in alkalies. In these characters it approaches much more closely the bekinkinites of Madagascar, which are a highly melanocratic type of ijolite. The name bekinkinite, proposed by Rosenbusch,[1] is based upon descriptions and analyses published by Lacroix.[2] The latter grouped the rocks in question among the ijolites, but pointed out that they are distinguished from other known ijolites, in their more melanocratic nature, in the absence of garnet, and in containing purple, instead of green, augite. The Ambaliha bekinkinite carries a little orthoclase, but apparently no plagioclase, and biotite, but no hornblende. The Bekinkina rocks, however, seem to be rich in barkevicite, while some of them contain plagioclase. They must approach the Barshaw theralite, or bekinkinite as it may well be called, very closely.[3] Rosenbusch points out that bekinkinite is the deep-seated form of nepheline-basalt. A glance at the table of analyses given above shows clearly that several ultrabasic rocks in the Central Valley of Scotland have a composition which places them near to the bekinkinites, so that the discovery of this new type of plutonic rock in the typically alkali province of Madagascar is specially welcome.

The *Milngavie Sills* (pp. 159-60) occupy a quite indeterminate petrographical position, so far as the grouping into teschenites and quartz-dolerites is concerned. They are hypidiomorphic olivine-free dolerites (12879) with abundant basic plagioclase felspar, pale augite, sometimes with a very faint purple tint, and titaniferous magnetite, the latter showing skeleton growths. There is a very small proportion of brown hornblende and biotite of the type met with in the teschenites. The mesostasis consists entirely of decomposition products such as chlorite and calcite without analcite. The absence of micropegmatite separates these sills very distinctly from the quartz-dolerites of the Kilsyth sills and the east-and-west dykes, but whether they should be regarded as aberrant members of this group or of the olivine-dolerite and teschenite series remains uncertain.

LAVAS AND ASSOCIATED INTRUSIONS OF CALCIFEROUS SANDSTONE AGE.[4]

The *macroporphyritic basaltic lavas* form a continuous rock series, but may be classified in a perfectly satisfactory manner according to the nature of their phenocrysts. Three basalts have been chosen as types in this classification, namely the Craiglockhart and Dunsapie basalts of Edinburgh, and the Markle basalt of East Lothian; the phenocrysts of these rocks are as follows :—

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[1] 'Mikroskopische Physiographie,' 1907, ii., p. 441.

[2] 'Matériaux pour la Minéralogie de Madagascar,' *Nouv. Archives du Muséum* (4), 1902, i., p. 135, and 1903, ii., p. 227, Paris.

[3] Dr. Tyrrell accepts this suggestion in his description of 'The Bekinkinite of Barshaw,' *Geol. Mag.*, 1915, p. 304.

[4] Two publications bearing closely upon the subject have appeared since the first edition of this memoir, namely :—G. W. Tyrrell, 'The Petrology of the Auchineden District, Kilpatrick Hills,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part iii., 1909, p. 337 ; and J. V. Harrison, 'Notes on the Geology of the East Kilsyth Hills,' *Trans. Geol. Soc. Glasg.*, vol. xv., part iii., 1916, p. 315.

	Craiglockhart.	Dunsapie.	Markle.
Augite	Abundant.	Abundant.	Absent
Olivine . . .	Do.	do.	Fairly Abundant.
Felspar . . .	Absent.	do.	Very abundant.

1. A Craiglockhart basalt has recently been described by Mr. Lothian[1] from a very low horizon in the Campsie sequence near Kilsyth. Similar lavas occur sparingly in the Kilpatrick Hills, forming a few scars immediately east and south-east of Black Loch, slightly beyond the western limit of the map.

The augite phenocrysts of these Black Loch lavas (12298) are purplish in colour, and zoned, while they sometimes show hour-glass structure and twinning; they have ragged margins owing to late additions having a sub-ophitic tendency, and in agreement with this the augite of the groundmass occurs in irregular little sub-ophitic crystals.

The olivine phenocrysts are large, numerous and in part fresh.

The constituents of the groundmass are labradorite, augite and magnetite, while small chlorite-filled interspaces suggest the former presence of a readily decomposed mineral or perhaps a little glass.

Though less alkaline, these rocks resemble the Lennoxtown essexite very closely indeed.

2. The Dunsapie basalts are distinguished from the Craiglockhart type by the presence of porphyritic bytownite or labradorite as an important constituent, while phenocrysts of augite begin to be less abundant. Very typical Dunsapie basalts are frequent in the upper part of the Kilpatrick succession. A conspicuous, though rather decomposed, example forms a crag 900 yds. west of High Craigton. Phenocrysts of plagioclase, olivine and augite make up nearly half the rock (12730). Very fresh and beautiful material can be obtained a quarter of a mile east of Boards (12562).

The groundmass consists of the same minerals as in the Craiglockhart basalts, with a tendency to be more felspathic. The augite of the second generation is often in well-formed microlites (12562). Analcite occurs in small amount in the type Edinburgh rock, and is present in some of the examples in this district.

A variety with but few augite phenocrysts, occupying a position midway between the Dunsapie and Markle types, is common in the Kilpatrick Hills. The groundmass differs from that of the true Markle basalts in being richer in microlitic augite. A good example gives rise to a crag 130 yds. from Dyke House, near Blanefield (12567).

Dunsapie basalts are abundant in the Cathkin Hills (12816), and intermediate varieties are met with in this locality linking them with the microporphyritic Dalmeny basalts with which they are associated.

3. Basalts referable to the Markle type have already been described from the Campsie district by Allport[2] and later by Mr. Lothian.[3]

They are especially well developed to the north of Kilsyth. They are also common in the Kilpatrick Hills. Many rocks are included here, for convenience, in which phenocrysts are rather scarce. Some have a microporphyritic base, and are in fact typical Jedburgh basalts with the addition of large labradorite phenocrysts. In the type Markle basalt of East Lothian there is an easily recognizable amount of orthoclase in the groundmass, but in the Markle basalts of the Campsie district this mineral seems to be distinctly less abundant.

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[1] *Loc. cit.*, p. 18.

[2] *Loc. cit.*, p. 558.

[3] *Loc. cit.*, pp. 16-22.

A peculiar specimen obtained north of Berryhill Farm, two miles north of Kilsyth (1140), has a micro-ophitic instead of the microlitic base generally characteristic of the Markle type. On this specimen Professor Watts[1] has founded his Kilsyth type, but it seems preferable to regard the rock as merely a rather unusual variety of the Markle basalt.

No analyses of the macroporphyritic basalts of the immediate district have been made, but we quote six analyses already published of similar Scottish rocks of Calciferous Sandstone age. It is obvious from a glance at the table that the Scottish Carboniferous macroporphyritic basalts form a series presenting fairly close chemical resemblance to the mineralogically similar series of the Norwegian essexites. The latter, it will be remembered, stand about midway between the typical essexites and the gabbros, and in like manner it may be said that the Carboniferous macroporphyritic basalts stand midway between the trachybasalts and the normal basalts.

	A.	I.	II.	III.	IV.	V.	VI.	B.
SiO_2 . . .	43·65	46·28	46·01	45·10	49·76	49·07	49·54	49·25
TiO_2 . .	4·00	2·06	—	2·66	2·01	—	—	1·41
Al_2O_3 . .	11·48	14·18	19·19	15·04	13·80	19·43	22·23	16·97
Cr_2O_3 . .	—	—	—	—	—	—	—	—
Fe_2O_3 . .	6·32	3·79	5·91	8·85	6·72	10·58	9·55	15·21
FeO . . .	8·00	7·34	6·75	4·62	7·68	2·35	1·12	
MnO . .	trace	0·09	0·19	0·45	—	0·32	0·08	trace
(Co,Ni)O . .	—	0·05	—	—	—	—	—	—
MgO . .	7·92	10·82	6·81	6·68	2·86	4·36	2·80	3·00
CaO . . .	14·00	9·88	8·68	8·75	7·46	7·87	7·19	7·17
SrO . . .	—	nt. fd.	—	—	—	—	—	—
BaO . .	—	nt. fd.	—	—	—	—	—	—
Na_2O . .	2·28	2·58	3·27	3·78	4·70	3·31	4·56	4·91
K_2O . . .	1·51	1·01	1·20	1·04	1·62	0·98	1·81	2·01
H_2O above 105° C	1·00	1·66	3·07	1·76	2·01	2·26	2·42	0·30
H_2O at 105° C. ..		0·31		1·31	0·54			
P_2O_5 . .	trace	0·44	—	0·56	0·39	—	—	0·76
	100·16	100·49	101·08	100·60	99·55	100·53	101·30	100·99

A. Augitic essexite, Brandberget, Norway. Anal. L. Schmelck; quoted from Brögger, *Quart. Journ. Geol. Soc.*, vol. l., 1894, p. 19.

I. Basalt, Craiglockhart type, near Redside, East Lothian. Anal. E. G. Radley; quoted from 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 121.

II. Basalt, Dunsapie type, Kippie Law Quarry, East Lothian. Anal. J. S. G. Wilson; quoted from Hatch, *Trans. Roy. Soc. Edin.* (1892), vol. xxxvii., 1895, p. 118.

III. Basalt, Dunsapie type, Duncomb Hill, Kilpatrick Hills, Sheet 30. Anal A. Scott; quoted from G. W. Tyrrell, *Trans. Geol. Soc. Glasg.*, vol. xiv., part iii., 1912, p. 201.

IV. Basalt, Dunsapie type, 1000 yds. from Faughlin Reservoir in the Fauglin Burn, north tributary, Sheet 31. Anal. J. V. Harrison; quoted from *Trans. Geol. Soc. Glasg.*, vol. xv., part iii., 1916, p. 323.

V. Basalt, near to Markle type, Hailes Castle, East Lothian. Anal. J. S. G. Wilson; quoted from Hatch, *loc. cit.*, p. 119.

VI. Basalt, Markle type, Markle Quarry, East Lothian. Anal. J. S. G. Wilson; quoted from Hatch, *loc. cit.*, p. 119.

B. Felspathic essexite, Dignaes, Norway. Anal. A. Damm and L. Schmelck; quoted from Brögger, *Quart. Journ. Geol. Soc.*, vol. l., 1894, p. 19.

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[1] Quoted by Sir A. Geikie, 'Ancient Volcanoes of Great Britain,' 1897, vol. i., p. 418.

The microporphyritic basalts form part of a continuous rock series linking the nepheline-basalts with the mugearites and albite-trachytes or keratophyres.

The discussion of the chemical composition of this series may be conveniently deferred until after the description of the mugearites and their allies. Meanwhile we may give an account of the four subdivisions adopted in what may be termed the basaltic portion of the series.

I. Augite-monchiquites, nepheline-basalts and limburgites:—these contain numerous small phenocrysts of olivine and purple augite in a felspar-free base rich in microlitic augite and magnetite with interstitial analcite, nepheline or glass. The type rock is the nepheline-basalt from Chester's Quarry, East Lothian; no representatives are known from the Glasgow district.

II. The Hillhouse type of basalt, very similar to the above, but with a little basic plagioclase felspar in the base, accompanied either by analcite or glass—nepheline has never been detected. The type rock comes from Hillhouse Quarry, near Linlithgow; no example is known from the Glasgow district.

III. The Dalmeny type of basalt, with abundant small olivine phenocrysts in a mesh of slender basic plagioclase crystals, microlitic augite and minute granules of magnetite; a little brown glass is sometimes present; felspar and augite phenocrysts are rare or absent. An extension of the type admits of coarser varieties in which the augite of the ground occurs in sub-ophitic granules. Such rocks can alternatively be described as fine-grained Galliston (misspelt Gallaston). basalts or dolerites. They are very characteristic, for instance, of the Millstone Grit volcanic horizon in Ayrshire.

The type rock comes from Dalmeny, West Lothian, and similar rocks, associated with Hillhouse basalts, constitute the volcanic masses of Bathgate and Burntisland. In the Glasgow district Dalmeny basalts figure very prominently in the Cathkin Hills (13146), but are rare, if at all represented, among the lavas of the Campsie-Kilpatrick succession; the freshest material, however, has been obtained from the centre of a compound dyke in a stream between Auchineden Hill and Little Caldon, north of the Kilpatrick Hills, and a mile west of the limits of the map. Specimens from this dyke (14074) contain fresh olivine in which there has been a most remarkable and abundant separation of magnetite, evidently due to resorption or corrosion.

Along with the more typical Dalmeny basalts of the Cathkin Hills there are certain others distinguished by the large size of their olivine phenocrysts (12827), which places them, strictly speaking, in the macroporphyritic series. Of more interest are the felspathic varieties (12813) leading to the Jedburgh type, which is represented in the same hills by one or two specimens (12807).

IV. The Jedburgh type of basalt, which is abundantly represented among the lavas, agglomerates and intrusions of the Campsie Fells, will be dealt with in some detail, as no opportunity has previously arisen for its exhaustive study.

The type includes a number of basalts and fine-grained dolerites which carry micro-phenocrysts of felspar and olivine in a nearly holocrystalline groundmass of felspar and augite. The structure of the original specimens from Jedburgh, in the Border Country, upon which Professor Watts[1] founded the type, is sub-ophitic to micro-ophitic, but while it remains true that sub-ophitic structure is very characteristic of the group as a whole, there are otherwise quite typical examples in the large suite met with in the Campsie Fells in which the groundmass is microlitic.

In the field the rocks are black or grey; and are massive, rarely platy, and seldom columnar—except where they occur as intrusions. Their porphyritic structure is inconspicuous, but close inspection generally reveals many small tabular felspar phenocrysts arranged in parallelism; little black pseudomorphs after olivine can also often be detected.

The tabular felspar phenocrysts range up to about two millimetres in length. They vary in composition from bytownite (12573) to acid labradorite (11811), while a mean or basic labradorite is of frequent occurrence (12267). Sporadic phenocrysts of the size met with in the Markle basalts are also present in a few flows.

The olivine phenocrysts are occasionally a millimetre long. They frequently show good crystal outlines, and sometimes occur in skeleton form (12570). Composite grains are common, but true olivine-nodules have not been observed. Intergrowths of olivine and felspar are met with in which both minerals show traces of idiomorphism at the internal junctions (12570). As a rule the olivine is fresh in the intrusions and decomposed in the lavas.

In typical specimens of the group felspar and olivine phenocrysts are about equally numerous, but the porportion varies greatly. Also, in general, the phenocrysts, although a conspicuous microscopic feature of the rock, play a subordinate rôle to the groundmass. In this connection it is interesting to notice the contrast between the slowly cooled interior and the rapidly chilled edge of the plug forming the western half of Barniemore (Fig. 6, p. 143). In the chilled edge (12574) the felspar phenocrysts are about half a millimetre long and make up a very small part of the rock; in the coarse interior (12573) they have increased to two millimetres in length, and alone compose about half the bulk of the rock, while the olivine phenocrysts show a similar increase in size. But the accentuation of the importance of the felspar phenocrysts at the expense of the groundmass is by no means the rule in the doleritic intrusions. Thus, in the massive plugs of Dunmore and Dungoil, near Fintry (Fig. 6, p. 143), it is the felspars of the groundmass which show the more important increase in their dimensions; while the porphyritic structure, apparently not strongly developed in these two rocks in the first instance, has become almost completely obscured. Instances of bent or broken phenocrysts, indicating yielding under pressure acting transverse to the flow structure during the protracted period of cooling, are not infrequent among these doleritic varieties (12572 and 12578).[2] The Dunmore and Dungoil rocks are distinctly micro-ophitic, and this, combined with their faintly marked porphyritic structure, brings them into very close agreement with Dr. Hatch's Galliston type. They differ from the latter, however, in being much poorer in olivine.

Before leaving the phenocrysts it may be mentioned that a large part of the magnetite, which is no doubt often intergrown with ilmenite, is of very early consolidation ; sometimes two generations are clearly distinguishable (12574, 12736), and in such cases the phenocrysts show the skeletal forms of ilmenite. The titaniferous magnetite is a constant and important accessory.

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[1] Quoted by Sir A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. i., 1897, p. 418.

[2] *Cf.* the broken columnar augites of the quartz-dolerites described by J. D. Falconer, *Trans. Roy. Soc. Edin.*, vol. xlv., 1908, p. 140, Plate ii., Fig. 3 (issued separately 1906).

Apatite occurs among the phenocrysts only in a very sporadic manner (13068).

The felspars of the groundmass resemble the phenocrysts, though they are probably of slightly more acid composition. They exhibit a less marked parallelism than their larger fellows.

The restriction of the augite to the groundmass is one of the great features of the Jedburgh type. Another characteristic is the tendency to micro-ophitic structure even among the lavas (12234). On the other hand, microlitic augite does occur occasionally in specimens which are otherwise quite typical, and this may happen even in well crystallized intrusive examples (12570). As a rule the augite has a well-marked purple tint.

Professor Zirkel[1] has drawn attention to the glassy globulitic base of the Dunglass basalt (Fig. 6, p. 143) belonging to the Jedburgh group. " The globulites are extremely minute yellowish brown or brown bodies, the largest of which are only ·004 mm. in diameter. Where these bodies are very numerous the glass appears a dark brown. They are without action on polarized light. Professor Zirkel remarks that the poverty of this rock in augite is compensated for by the abundance of the brown globulites in the base."

As a rule glass can only be rarely detected, but analcite is of more common occurrence, at least in the fresh intrusive examples of the type that yield the best material for study. It occurs in interspaces as in the teschenites, but never in large amount (12267).

With decreasing augite, and increasing alkalinity of the felspars, the Jedburgh basalts (13068, 13083) assume a very mugearitic appearance. In fact it appears that the two groups are inseparably linked together.

The mugearites are fine-grained rocks with trachytic structure, for the most part composed of oligoclase felspar associated with orthoclase ; magnetite is almost always present in abundance, olivine is common, and often very prominent, but in other cases it fails altogether ;[2] small flakes of late-formed biotite and hornblende are very characteristic, especially in types poor in olivine ; augite is always present in the groundmass of fresh examples, and although markedly less abundant than in the basalts, it is probably, on the whole, the most persistent ferromagnesian element of the mugearites. Apatite is a conspicuous accessory.

The type was defined by Dr. Harker,[3] who described Tertiary examples from Skye. Soon afterwards Mr. Barrow[4] showed that similar rocks occurred in the Carboniferous volcanic series of East Lothian, and later Sir John Flett[5] determined the nature of the small flakes of biotite and hornblende which occur in many mugearites hailing from such widely separated localities as the Hebrides and the Lothians.

In the field the mugearites are distinguished from the Jedburgh

[1] 'Basaltgesteine,' Bonn, 1870, p. 139 ; quoted from Teall, 'British Petrography,' 1888, p. 194.

[2] *Cf.* A. Harker, 'The Geology of the Small Isles of Inverness-shire,' *Mem. Geol. Surv.*, 1908, p. 132.

[3] 'Tertiary Igneous Rocks of Skye,' *Mem. Geol. Surv.*, 1904, pp. 264-269.

[4] 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 123.

[5] 'On the Mugearites,' Summary of Progress for 1907, *Mem. Geol. Surv.*, 1908, pp. 119-126.

basalts by their pale weathering tints, and, where not extremely slaggy, by their fissile platy structure. The latter is apparently determined by the existence of shear planes or "rucks," which came into existence during the latest stages of flow after almost complete crystallization.

The mugearites of the Campsie-Kilpatrick district are either microporphyritic or non-porphyritic.

The plagioclase felspar of the mugearites proper is oligoclase, but andesine and perhaps labradorite are met with in basaltic varieties (13934, 14130 Analysis IV., p. 182). Orthoclase can sometimes be detected with fair certainty grown about the plagioclase laths. In the analysed specimen (13114, 13354, Analysis VI.) the texture is very fine and the bulk of the felspar may perhaps be soda-orthoclase. There has been very little olivine originally present in this particular rock, but the abundant magnetite links it with the mugearites. Albitization is certainly of frequent occurrence in this group, and phenocrysts are occasionally seen albitized in thoroughly characteristic patchy fashion (13123). In many instances it is difficult to be certain whether albitization has occurred or not. It may for instance have affected the analysed specimen VI., but there is no evidence that such is the case. The point is of interest, because, associated with the mugearites are certain *albite-trachytes or keratophyres*[1] (13078), carrying olivine pseudomorphs and abundant magnetite. The felspar of these rocks is albite and is apparently original, but it is difficult to be certain on this point. The best material of true oligoclase-mugearite, so far as the unaltered state of the felspars is concerned, was obtained from the summit of the Little Bin (13084).

The olivine of the Carboniferous mugearites is almost always decomposed, but is in part fresh in the analysed specimen IV. In many cases its pseudomorphs are very abundant, as in the small intrusion a mile north-east of Fintry (13933, *see* Fig. 6, p. 143). In other cases very few pseudomorphs after olivine can be found, as in the analysed specimen VI. The decomposition of the olivines is probably partly determined by the platy structure of the mugearites which favours weathering.

The interesting late-formed little patches of brown hornblende and biotite which have been met with in the mugearites of Skye, Eigg, Muck and the Lothians, have been detected also, in several cases, in the mugearites of the Campsie - Kilpatrick succession. Both minerals are especially prominent in the basaltic mugearites (Analysis IV.), but even here they make up but a small fraction of the rock. Their habit is ophitic. The biotite is most readily distinguished from the hornblende by the extraordinary blue and peacock green colours it frequently exhibits between crossed nicols. Sir John Flett has shown that it owes this character to the great dispersion of its optic axes. The cleavage of the minerals and their different behaviour in convergent polarised light also serve to distinguish the one from the other.

Analyses of microporphyritic series.—A table of analyses is given illustrating the chemical characteristics of the rock series which includes the microporphyritic basalts and the mugearites of the Central Valley of Scotland. It has already been pointed out that the Chester's Quarry nepheline-basalt (I.) and the very similar Hillhouse basalt (II.) are closely allied to the bekinkinites in composition (p. 174). The Jedburgh type of basalt (III.) obviously occupies a position on the border

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[1] Much resembling the anorthoclase-keratophyres of Caradoc age described by Sir Jethro Teall from Peeblesshire, 'The Silurian Rocks of Britain,' vol. i., *Mem. Geol. Surv.*, 1899, p. 88.

	I.	II.	III.	IV.	V.	VI.	VII.	A.
SiO_2 . . .	40·2	42·49	46·45	50·06	49·29	50·29	50·24	49·24
TiO_2 . .	2·9	2·51	3·11	2·46	2·27	1·67	3·09	1·84
Al_2O_3 . .	12·8	13·85	16·98	15·72	16·66	18·11	15·01	15·84
Cr_2O_3 . .	—	—	—	—	—	—	—	trace
Fe_2O_3 . .	4·0	2·59	3·94	3·94	7·24	4·09	8·94	6·09
FeO . . .	10·4	9·32	8·57	7·63	4·81	8·06	6·46	7·18
MnO . .	—	0·29	0·48	0·30	0·55	0·65	—	0·29
(CO,Ni)O .	—	0·09	nt. fd.	0·03	0·04	nt. fd.	—	trace
MgO . .	11·9	11·21	5·94	3·82	2·42	3·32	3·16	3·02
CaO . . .	10·4	9·76	7·64	5·90	5·63	1·70	5·61	5·26
SrO . . .	—	—	—	—	—	nt. fd.	—	trace
BaO . .	—	0·04	nt. fd.	0·03	? trace	nt. fd.	—	0·09
Na_2O . .	2·7	2·39	3·50	4·55	4·98	5·06	3·47	5·21
K_2O . . .	0·8	0·87	1·43	2·16	1·86	2·65	1·91	2·10
Li_2O . .	—	nt. fd.	? trace	nt. fd.	trace	? trace	—	—
H_2O above 105° C.	3·4*	3·35	1·68	1·36	2·11	3·45	1·77	1·61
H_2O at 105° C. .		0·47	0·24	0·67	0·34	0·86	1·05	1·08
P_2O_5 . .	—	0·61	0·51	0·64	0·24	0·44	—	1·47
CO_2 . . .	—	0·22	0·41	1·08	2·32	nt. fd.	—	—
Cl . . .	—	—	—	0·04	? trace	—	—	—
F . . .	—	—	—	—	—	—	—	0·18
S . . .	—	—	—	—	nt. fd.	—	—	0·03
FeS_2 . .	—	nt. fd.	trace	nt. fd.	—	0·06	—	—
Fe_7S_8 . .	—	—	0·06	—	—	—	—	—
	99·5	100·06	100·94	100·39	100·77	100·41	100·71	100·53
		Less O for Cl		0.01		Less O for F		0·07
				100·38				100·46

* Loss on ignition.

I. Nepheline-basalt ('Limburgite'), Chester's Quarry, E. Lothian. Anal. J. H. Player; quoted from Hatch, *Trans. Roy. Soc. Edin.* (1892), vol. xxxvii., 1895, p. 116.

II. Basalt, Hillhouse type, Hillhouse Quarry, near Linlithgow (14075). Anal. E. G. Radley.

III. Basalt, Jedburgh type, small intrusion, Little Caldon Neck, N. of Kilpatrick Hills (13303). Anal. E. G. Radley.

IV. Basaltic mugearite, lava, west one of two knobs (1500 ft.), hill-top half a mile N. by E. of Balhennan Farm, Fintry Hills (14130). Anal. E. G. Radley.

V. Mugearite, Corston Hill, Midlothian. Anal. W. Pollard; quoted from Flett, 'On the Mugearites,' Summary of Progress for 1907, p. 125.

VI. Mugearite, lava, 500 yds. S. 30° W. of the cairn on Lairs above Lennoxtown, 5th flow above lowest porphyritic basalt (13354). Anal. E. G. Radley.

VII. Mugearite, lava, Creag a' Mhara, S. Bute. Anal. J. V. Harrison, quoted from W. R. Smellie, *Trans. Geol. Soc. Glasg.*, vol. xv., part iii., 1916, p. 359.

A. Mugearite, Druim na Criche, Skye. Anal. W. Pollard; quoted from Harker, 'Tertiary Igneous Rocks of Skye,' *Mem. Geol. Surv.*, 1904, p. 263.

of the essexite province, and may accordingly be classed either as a basalt or a trachybasalt.[1] In the mugearites (IV., V. and VI.) the essexite composition predominates. As Dr. Harker pointed out when he first established the group, the only important point, distinguishing the mugearites chemically from the Dignaes essexite of Christiania (Analysis B., p. 177), is their lower lime content. The mugearites may therefore be regarded as a special subdivision of the trachybasalts, extending, perhaps, into the trachyandesites.[2]

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[1] Trachybasalt replaces trachydolerite (of 1st edition) on the recommendation in 'Report on British Petrographic Nomenclature,' *Min. Mag.*, vol. xix., 1921, p. 144. It is understood, however, that the word *intermediate* applied to trachybasalts in this 'Report' does not refer to silica content. Trachybasalts are basic rocks with less than 55 per cent. SiO_2.

[2] All analysed mugearites, except one, show less than 55 per cent. SiO_2. A specimen described in 'Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban,' *Mem. Geol. Surv.*, 1924, has 55·76 per cent SiO_2. It may eventually prove convenient to exclude such more acid rocks from the mugearites; but the question must be left open for the present.

It should be remembered that the particular low lime content of VI. may perhaps be due to albitization of the felspars, but of this there is no evidence.

A *trachybasalt*, of quite different character from the mugearites, is represented by an intrusion in the northern part of the Meikle Bin vent (Fig. 6, p. 143). It is a black rock with conspicuous phenocrysts of felspar, augite and olivine. Under the microscope (13085) the olivine crystals are seen to be well formed and fairly numerous; they are almost all converted to serpentine and calcite. Augite, of a rich purple colour, is represented by a few phenocrysts, sometimes greatly corroded, and by an abundance of small, well-formed prisms, occurring in the groundmass. The felspar phenocrysts consist of labradorite with very thin outer zones of orthoclase. In the ground-mass plagioclase and orthoclase are present in roughly equal proportions. Magnetite is very abundant, and occurs in two generations. Apatite is also represented.

From this account it will appear that the intrusion resembles the Dunsapie basalts, but is distinguished by the abundance of orthoclase. It may also be compared with the shoshonites described by Iddings[1] from the Yellowstone Park, and there can be no question as to its thoroughly essexitic composition.

	I.	II.	III.	A.	B.	C.	D.
SiO_2 . . .	60·56	58·50	62·61	62·38	59·22	58·88	58·48
TiO_2 . . .	0·79	—	—	—	—	—	0·96
Al_2O_3 . . .	16·51	21·12	18·17	16·88	13·59	20·30	19·24
Fe_2O_3 . .	3·12	4·68	0·32	7·33	5·54	3·63	5·75
FeO . . .	3·77	—	4·25	—	4·03	2·58	
MnO . . .	0·39	—	0·21	trace	—	—	trace
(Co,Ni)O . .	nt. fd.	—	—	—	—	—	—
MgO . . .	0·61	0·93	0·74	0·82	1·66	0·79	0·99
CaO . . .	3·08	3·70	2·58	3·49	5·13	3·03	5·02
BaO . . .	0·03	—	—	—	—	—	—
Na_2O . . .	5·57	3·90	6·49	4·42	5·31	5·73	5·52
K_2O . . .	3·71	5·84	4·02	2·94	4·64	4·50	3·06
Li_2O . . .	nt. fd	—	—	—	—	—	—
H_2O above 105°C. .	0·76	2·00†	0·80†	0·87†	1·25†	1·01	0·47
H_2O at 105° C. .	0·97	—	—	—	—	—	—
P_2O_5 . . .	0·19	—	—	—	—	0·54	—
CO_2 . . .	0·25	-	—	—	—	—	-
FeS_2 . . .	nt. fd.	—	—	—	—	—	—
	100·31	100·67	100·19	99·13	100·37	100·99	99·49

† Loss on ignition.

I. Trachyandesite, lesser peak of Meikle Bin, Campsie Fells (14073). Anal. E. G. Radley.

II. Quartz-banakite ('trachyte'), Bangly Quarry, East Lothian. Anal. A. Dick, jun.; this and succeeding analysis quoted from Hatch, *Trans. Roy. Soc. Edin.* (1892), vol. xxxvii., 1895, p. 122. *See also* 'The Geology of East Lothian,' *Mem. Geol. Surv.*, 1910, p. 133.

III. Porphyritic trachyte, Peppercraig, East Lothian. Anal. J. S. G. Wilson.

A. Trachyandesite, Wolkenburg, Siebengebirge; quoted from Rosenbusch, 'Elemente der Gesteinslehre,' 1910, p. 388.

B. Trachyandesite, Stenzelberg, Siebengebirge; quoted from Rosenbusch, *loc. cit.*, p. 388.

C. Laurvikite, Byskoven near Laurvik; quoted from Rosenbusch, *loc. cit.*, p. 132.

D. Akerite, quartz-bearing, Ramnäs, Norway; quoted from Rosenbusch, *loc. cit.*, p. 132.

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[1] 'Geology of the Yellowstone Park,' *Mon. U.S.G.S.*, vol. xxxii., 1899, part ii., p. 339.

Forming the southern peak of the Meikle Bin, is a *trachyandesite* intrusion that bridges the gap between the trachybasalt just described and the trachytes proper. In hand specimens it has a much less basaltic appearance than the trachybasalt, and under the microscope (14073), while it shows very similar phenocrysts—labradorite, faintly purple pleochroic augite, olivine (as pseudomorphs) and magnetite—these are set in a thoroughly orthophyric ground in which augite, magnetite and plagioclase felspar play a very subordinate rôle.

Mr. Radley's analysis shows how closely the Meikle Bin trachyandesite agrees in composition with the Bangly quartz-banakite and the allied Peppercraig trachyte, both of them well-known East Lothian rocks, and also with the hornblende trachyandesites of the Siebengebirge. On comparison with analyses of plutonic rocks, the Meikle Bin trachyandesite is found to correspond more closely with the laurvikites and akerites than with the monzonites.

The *Fintry phonolite* (Fig. 6, p. 143) can only be obtained fresh from a small exposure at the roadside at the eastern entrance of the village known as the Newton o' Fintry. In the hand specimen it is a red rock with dark spots, and under the microscope (13310) it proves to be a very typical trachytic phonolite. It is non-porphyritic, and consists for the most part of orthoclase laths, while the dark spots are exceedingly ragged ophitic crystals of deep green aegirine and pale green aegirine-augite. Nepheline, in large measure quite fresh, is abundant in small idiomorphic crystals which are particularly conspicuous where they occur partially embedded in the aegirine or the augite. Magnetite and analcite are present as minor accessories.

The Fintry phonolite bears a fairly close mineralogical resemblance

	I.	II.	A.
SiO_2	57·98	56·89	56·49
TiO_2	0·20	0·33	0·74
Al_2O_3	17·92	19·11	18·77
Fe_2O_3	4·23	2·04	3·00
FeO	2·72	3·44	1·46
MnO	0·21	0·18	0·32
(Co,Ni)O	nt. fd.	nt. fd.	—
MgO	0·34	0·35	0·63
CaO	2·12	2·15	3·29
SrO	nt. fd.	—	—
BaO	nt. fd.	0·01	—
Na_2O	6·99	6·88	7·10
K_2O	5·24	6·35	5·18
Li_2O	? trace	nt. fd.	—
H_2O above 105° C.	1·76	1·68	1·83
H_2O at 105° C.	0·64	0·54	0·62
P_2O_5	0·08	0·15	0·27
CO_2	nt. fd.	nt. fd.	1·00
SO_3	—	trace	—
FeS_2	nt. fd.	0·17	—
Cl	—	0·22	—
		100·49	
Less O for Cl		0·05	
	100·43	100·44	100·70

I. Trachytic phonolite, roadside, Newton o' Fintry (13310). Anal. E. G. Radley.

II. Trachytic phonolite, Traprain Law, East Lothian. Anal. F. R. Ennos; quoted from *Geol. Mag.*, 1922, p. 522.

A. Trachytic phonolite, Ziegenberg, near Nestersitz, Bohemian Mittelgebirge; quoted from Rosenbusch, 'Elemente der Gesteinlehre,' 1910, p. 360.

to the well-known Traprain Law phonolite[1] described by Dr. Hatch, and Mr. Radley's analysis shows that the chemical correspondence of the two rocks is exceedingly striking.

Trachytes are abundant in the central region of the Campsie Fells round the Meikle Bin centre. Their presence, as has already been pointed out, was first made known by Sir A. Geikie, and they have since been described by Mr. Lothian.[2] They occur as irregular intrusions of small extent, often forming short dykes. They generally weather yellow or pink in the field and are either porphyritic or non-porphyritic. Under the microscope they prove to be too decomposed for satisfactory study, but probably present a greater variety of types than is known from the East Lothian centre described by Dr. Hatch. Biotite-trachytes (13099) and others with moss-like pseudomorphs (13094) suggestive of a soda-amphibole have been noticed.

Felsites.—Felsitic intrusions are abundantly associated with the trachytes referred to above, but most unfortunately they are all too decomposed for definite determination. The most conspicuous examples are furnished by a thick transgressive sheet or dyke with highly columnar centre, easily picked out on the hill face to the north of Lennoxtown (13345), and by the lacolithic intrusion to the east of Meikle Bin (13098). These felsitic rocks have a patchy microcrystalline ground surrounding a few felspar phenocrysts replaced by calcite. Quartz occurs in small aggregates scattered through the base, and is probably in large measure secondary. A specimen from the dyke above Lennoxtown has been analysed, but its decomposed nature renders the results somewhat unsatisfactory.

SiO_2	69·48
TiO_2	0·14
Al_2O_3	11·99
Fe_2O_3	2·54
FeO	2·46
MnO	0·20
(Co,Ni)O	0·03
MgO	1·16
CaO	1·72
SrO	nt. fd.
BaO	nt. fd.
Na_2O	3·33
K_2O	4·01
Li_2O	trace
H_2O above 105° C.	1·56
H_2O at 105° C.	0·32
P_2O_5	0·08
CO_2	1·34
FeS_2	0·05
	100·41

Felsite, 700 yds. S.S.E. of the cairn on Lairs, one and a half miles N. of Lennoxtown (13345). Anal. E. G. Radley.

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[1] Mr. A. G. MacGregor has confirmed Hatch and Rosenbusch in their recognition of nepheline in the Traprain Law phonolite, and has also proved the occurrence of sodalite: 'The Traprain Law Phonolite. Part I.: Nepheline, Analcite, Sodalite, and Olivine in the Traprain Law Phonolite, by A. G. MacGregor. Part II.: Analysis of the Traprain Law Phonolite, by F. R. Ennos,' *Geol. Mag.*, 1922, p. 514.

[2] *Loc. cit.*, pp. 13, 25.

QUARTZ-DOLERITE SILLS OF KILSYTH (p. 153), AND THE EAST-AND-WEST DYKES (p. 156).

The quartz-dolerite intrusions will be treated very briefly here, as but a small portion of the Kilsyth sills lie within the border of the map. The subject has also been dealt with recently by Dr. Tyrrell,[1] and there is, moreover, a large literature bearing upon the similar intrusions to the east, including Sir John Flett's account in the Geological Survey Memoir on the Edinburgh District.

The quartz-dolerite intrusions do not belong to any branch of the alkali family, and are accordingly distinctly removed in petrological affinity from the volcanic rocks and intrusions considered in the preceding pages. They may briefly be described as olivine-free subophitic dolerites, consisting essentially of basic plagioclase felspar and augite, with abundant titaniferous magnetite and a mesostasis, sometimes of glass, but more often of micropegmatite. The less crystalline varieties are known as tholeiites. All are non-porphyritic. Hypersthene not infrequently accompanies the monoclinic pyroxene, and the latter does not show the strong purple tint so characteristic of the basic intrusions heretofore described.

Thoroughly fresh specimens of vitrotholeiites belonging to this suite, with glassy base still undecomposed, had not been met with before Mr. Lothian[2] was fortunate enough to collect from the quarry a quarter of a mile N.W. of Kinkell, where a typical east-and-west dyke is exposed, fresh and vitreous throughout its whole thickness—though in some bands considerably more glassy than in others. This beautiful rock presents many of the characters of well-known Tertiary north-west dykes such as that of Eskdalemuir in the southern uplands.

It consists of numerous stout little columns of bytownite about 1 mm. long, somewhat subordinate pale brown augite, in more or less irregular grains, rudely shaped octahedra of magnetite and an abundant vitreous or variolitic base.

Where they come in contact, magnetite is idiomorphic to augite, and augite to felspar. The latter is remarkably unzoned, but just at the margin the bytownite not infrequently merges into oligoclase, which sometimes extends out into brush-like growths springing from the ends of the main crystals (13833). Similar brushes and variolitic sheaves often recur in the base, and in such cases it is impossible to be certain that the felspar is not orthoclase. A second generation of augite is also met with in the form of long needles and complicated skeletal growths such as are common in pitchstones. An abundant crop of very small magnetite crystals is frequently found attached to all the earlier crystals including the skeletal growths just mentioned. Apatite also occurs building long slender needles. In the more glassy varieties (13832) there are minute crystals which look like needles but may not improbably be thin flakes seen in cross section. They are distinctly brown in colour and pleochroic, and give straight extinction. They may be biotite, but their minute dimensions render a determination difficult.

A very interesting feature of the quartz-dolerites is their instability at temperatures slightly above the consolidation point, if this term, consolidation point, can be employed in regard to a rock. The result is a segregation of darker and paler patches,[1] the latter with pink felspathic groundmass enclosing branching acicular crystals of augite.

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[1] 'Geology and Petrology of the Intrusions of the Kilsyth-Croy District, Dumbartonshire,' *Geol. Mag.*, 1909, p. 299.

[2] *Loc. cit.*, p. 15.

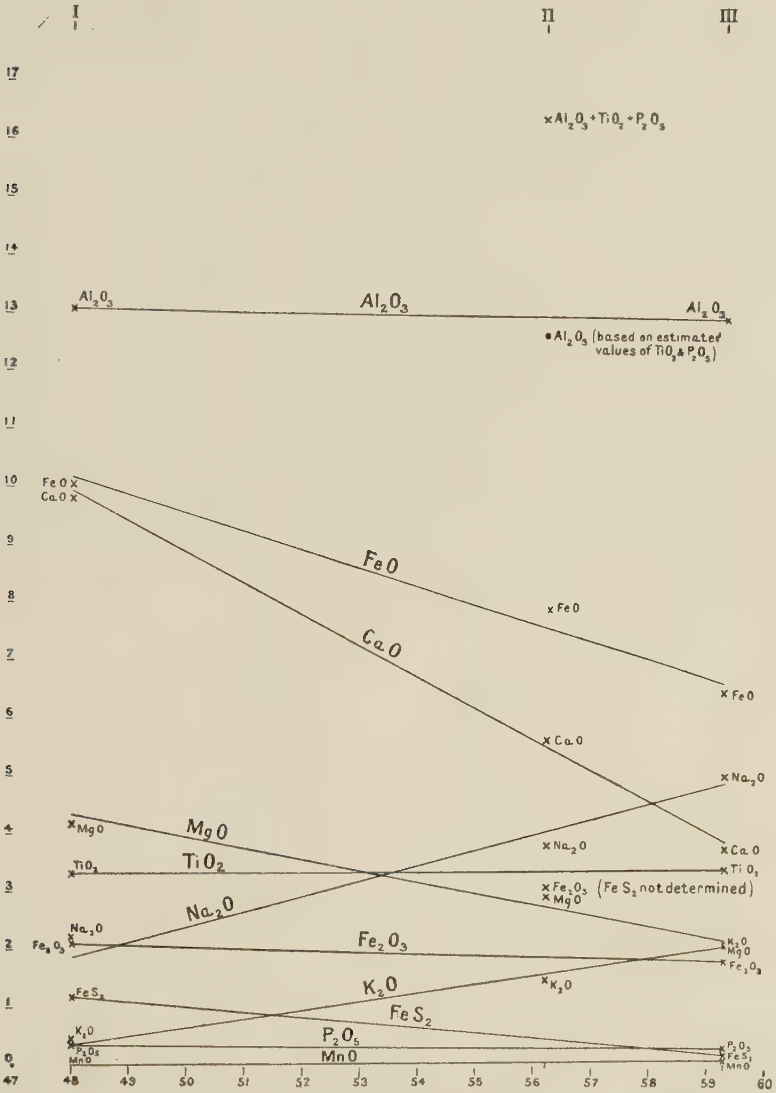

FIG. 9.—Composition-Diagram of Quartz-Dolerite, etc., based upon analyses by G. S. Blake, quoted by J. D. Falconer, *Trans. Roy. Soc. Edin.*, 1906, vol. xlv., 1908, p. 147. SiO_2 per cent. plotted as abscissæ, other constituents as ordinates. I. Dark-coloured modification, Kettlestoun Quarry, Linlithgow. II. A mean type, Carribber Quarry, Linlithgow. III. Light-coloured modification, Kettlestoun Quarry, Linlithgow. The Kettlestoun and Carribber sills are distinct members of the Linlithgow sill complex.

The diagram (Fig. 9) shows how perfectly complementary these dark

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[1] Portions with more than 55 per cent. of SiO_2 are craignurite rather than quartz-dolerite. *Cf.* H. H. Thomas and E. B. Bailey in 'Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban,' *Mem. Geol. Surv.*, 1924, p. 227.

(I) and pale (III) patches are with respect to the mean rock (II). It must not be supposed, however, that the differentiation interpretation is based upon this diagram, since similar "straight line" variation would result if, for instance, both the mean and acid phase were derived from the basic phase by admixture with some acid dilutant of fixed composition. The differentiation interpretation is in fact based upon field observations,[1] and the comparatively low temperature at which it took place is vouched for by the patchy, as opposed to streaky, arrangement of the differentiation products, unmodified by subsequent flow. Recent work has shown that this differentiation has resulted through partial crystallization, combined with a certain amount of migration of the residual liquor. The subject is dealt with by Dr. Thomas, and the writer, in Chapter XXX. of the Geological Survey Memoir on the "Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban."

While the three analyses from the Linlithgow sill complex, plotted in Fig. 9, show an extremely perfect straight line variation, it soon becomes apparent that more complicated relations hold in other cases. Thus, using other analyses by Mr. Blake from the same complex, it is found that neither the margin nor the abundant soda-aplite veins fall into the straight line scheme illustrated in the figure; and, turning further afield, it is also found that neither the Whin Sill analysis given by Sir Jethro Teall nor the Kilsyth analysis by Mr. Macdonald can be accommodated in the diagram. Mr. Macdonald's analysis is quoted below.

SiO_2	49·80
TiO_2	1·56
Al_2O_3	17·77
Fe_2O_3	2·29
FeO	8·75
MnO	trace
MgO	5·67
CaO	8·85
Na_2O	1·48
K_2O	0·48
$H_2O(+)$	2·62
$H_2O(-)$	1·04
P_2O_5	trace
	100·31

Quartz-dolerite, Auchinstarry, Kilsyth. Anal. D. P. Macdonald; quoted from Tyrrell, *Geol. Mag.*, 1909, p. 361.

It will be seen that the total alkalies (1·96) are well beneath the 4 per cent., which may be taken as about the upper limit for a normal gabbro with less than 50 per cent. of silica. The dark modification of the Linlithgow sill with 48·02 per cent. silica has 2·66 total alkalies, but the Whin Sill with 50·71 per cent. silica has 4·15 alkalies, and an allied rock from St. Davids, in Wales, with 50·55 per cent. silica has 4·63 per cent. alkalies.

E. B. B.

IV. Zeolites of the Kilpatrick Hills.

The Kilpatrick Hills have long been famous for the handsome specimens of this group of minerals which are to be found among them.

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[1] *Cf.* J. D. Falconer, 'The Igneous Geology of the Bathgate and Linlithgow Hills,' *Trans. Roy. Soc. Edin.*, vol. xlv., 1908, p. 137 (issued separately 1906).

These minerals are generally found filling the vesicles and interstices of the slaggy and scoriaceous surfaces of the flows, but are sometimes also met with in little veins running through the rock. As might be expected, they do not occur in connection with all the lavas, but only with the more felspathic members, such as basalts of the Markle type and mugearites. They are practically never met with in basalts of the Dunsapie or Craiglockhart types. Analcite is one of the commonest minerals of the group and is generally found in small crystals lining vesicles ; but it also occurs in pellucid crystals half an inch across, or more, in cavities in a basalt flow about half a mile west of High Craigton, where it is associated with radiating quartz crystals. The icositetrahedral form is universal and does not appear to be modified by the occurence of any other faces.

Stilbite and *heulandite* are often associated together in the same localities, though they seldom occur mixed in the same specimen. The beautiful red colour of specimens of these minerals from the Kilpatrick Hills has made them so well known that it is unnecessary to enter into any details. The stilbite forms sheaf-like twinned crystals which attain a length of 1½ in., and are terminated by the form m[110], which is occasionally modified by the presence of a[100]. The heulandite occurs in the characteristic coffin-shaped crystals, but c[001] is not so prominent as is usually the case, and accordingly the crystals assume a pointed habit. The form b[010] shows the characteristic pearly lustre, but is not so highly coloured as the other faces. This suggests that the colouring matter is not an actual component of the crystal, but has infiltrated along cleavage cracks and does not affect the centre of the crystal There is nothing to suggest that the difference in colour is due to pleochroism. In small crystals the face is almost flat, but in larger crystals it shows strong curvature, so that the latter assume a sheaf-like habit not altogether unlike that of stilbite.

Prehnite, though not a member of the group, may be mentioned here as it occurs under the same conditions as the zeolites. It cannot be regarded as a common mineral in this area, but when found it is present in considerable abundance. The mineral was never actually observed in place, but large quantities are to be seen on a tip heap west of Deil's Craig Dam, where it is found lining irregular cavities in basalt. The crystals are never distinct, as the mineral builds botryoidal masses and globular groups which can be seen when examined to show repeated angles and faces. The mineral is translucent and pale reddish grey in colour.

ZEOLITE LOCALITIES.

(1-5 *Dumbartonshire ;* 6-9 *Stirlingshire.*)

1. On the east bank, about 300 yds. down the stream flowing from Black Loch (west of the border of the map). Stilbite.
2. 200 yds. north of the west end of the reservoir, one-third of a mile east of Black Loch. Stilbite.
3. 300 yds. E.N.E. of east end of same reservoir. Stilbite, analcite, and radial aggregates of the natrolite group.
4. In bed of stream about a quarter of a mile N.W. of Byshot. Fine crystals of heulandite and stilbite embedded in calcite.
5. On north bank of small stream near 800 ft. contour, half a mile W.N.W. of High Craigton. Analcite in large crystals associated with quartz.

6. In stream, 50 yds. below Milngavie Mill. Stilbite.

7. On road, 200 yds. N.W. of Carbeth. This locality is noted by Dr. Jack and mentioned by Heddle, who records heulandite, stilbite, laumontite, and natrolite.

8. In plantation, about 20 yds. from east shore, 250 yds. south of the north end of Craigallian Loch. Abundant heulandite in slaggy top of a bed.

9. Tip heaps at intervals along the line of the Loch Katrine aqueducts, where these traverse the lavas south of Strathblane. Zeolites are to be found in most of the tip heaps, but that near Deil's Crag Dam is the richest. Analcite, laumontite, stilbite, thomsonite (according to Heddle) and also prehnite. G. W. G.

CHAPTER IX.

GEOLOGICAL STRUCTURE.

THE sedimentary strata of the Glasgow area occupy a part of a great basin, whose axis extends roughly in a north-easterly direction through the Central Valley of Scotland, and whose centre lies around Uddingston, in the extreme south-eastern corner of the map. The greater part of the ground therein represented is therefore occupied by the rocks which form the north-western limb of this fold.

This general synclinal arrangement is modified, in the area under description, by a succession of minor undulations, truncated by a system of approximately parallel faults.

GENERAL SECTION ACROSS THE GROUND.

The horizontal section, on the scale of one inch to a mile, which will be found engraved on the Glasgow District Map, shows the general structure of the country along a line drawn across the centre of the area from the northern slopes of the Campsie Fells to the Necropolis in Glasgow, and thence to Capelrig on the volcanic plateau to the south.

At the northern end of the section the Upper Old Red Sandstone is shown dipping beneath the Cementstone or Ballagan Group of the Calciferous Sandstone sediments. These are succeeded by the overlying contemporaneous volcanic rocks, the section also crossing one of the volcanic vents of the region, and an east-and-west quartz-dolerite dyke.

The effect of the Campsie fault in bringing down the upper sedimentary group of the Calciferous Sandstone is next represented, and the rest of the section illustrates the arrangements of the Carboniferous strata of the central plain in a series of gentle undulations broken by numerous normal faults. An anticline, on which beds a short distance beneath the Index Limestone are brought to the surface near Bishopbriggs, is flanked on either side by complementary synclines. The centre of the basin to the north, beneath the thick drift deposits of the buried Kelvin valley, is occupied by Millstone Grit strata, while the southern syncline of the Clyde valley contains beds some little way up in the Barren Red Measures. The Coal Measures are abruptly truncated south of the river by the Dechmont fault, on whose upthrow side Carboniferous Limestone rocks are again brought to the surface in the Arden basin until, at the margin of the map, they are faulted down against the lavas of the southern volcanic plateau.

In the following paragraphs the structure of each of the principal areas is described and frequent use is made of horizontal sections across the ground. L. W. H.

Campsie and Kilpatrick Hills.

The rocks of the Campsie Fells have a general gentle inclination towards the south-east, with many minor undulations. The heights above Lennoxtown mark the position of a shallow syncline, and the central district, east of Meikle Bin, is arched into a gentle dome, determined perhaps by the presence of a felsite laccolith, now partially exposed to view.

The structure of the Kilpatrick Hills, south of the Campsie fault, is very different. Here the south-easterly dip is more pronounced, and continues steadily until the lavas pass beneath the overlying sediments. E. B. B.

Campsie and Milngavie Area.

Two horizontal sections are sufficient to illustrate the simple structure of this district. This section represented by Fig. 10 is drawn in a northerly direction through the South Hill of Campsie and across the valley of the Glazert to the Campsie fault.

The strata have a slight general dip to the south. The sandstones of Craigmaddie Muir, together with the higher beds of the Upper Sedimentary Group of the Calciferous Sandstone, occupy a wide area near Lennoxtown through the denudation of the almost horizontal overlying strata. The cap of Hurlet metals on the South Hill dips through the hill to the south at very gentle angles, the slight basin-shaped arrangement of the beds being due to trough faulting. Further south three powerful faults, each with a downthrow to the south tilt the strata in the same direction and bring on higher beds until the Millstone Grit occupies the surface at Balmore.

The second section (Fig. 11) runs from near Mugdock east through the South Hill of Campsie to Milton. At the west end of the section the volcanic series emerges from beneath the sandstone and conglomerates of Craigmaddie Muir. The basin-shaped arrangement of the Hurlet metals on the South Hill is in this case due to the beds occupying a gentle synclinal fold, in contrast to the previous north and south section of the hill.

The Hurlet metals appear again to the east of the Campsie Alum Works in another small syncline, being let down by a small fault (A) with a downthrow to east. At Milton the more powerful Queenzieburn fault (B), occupied by a dolerite dyke, throws down the strata to the east for between 300 and 400 fms., bringing the Calmy Limestone almost opposite the Hurlet Seam. The trend of these faults is N.E. and S.W., but they are continuous with the general east-and-west system of dislocations.

Kirkintilloch and Kilsyth.

In this area we pass from the simple structure of the South Hill of Campsie into a more complicated region, where the greater intensity of the movements has increased the amount of folding and faulting hitherto noticed. This belt of disturbance extends eastwards along the south side of the Campsie fault (the north side being practically unaffected—*see* p. 208), and passes beyond the limits of the Glasgow District Map, where it may be studied in the new edition of Sheet 31 (1924).

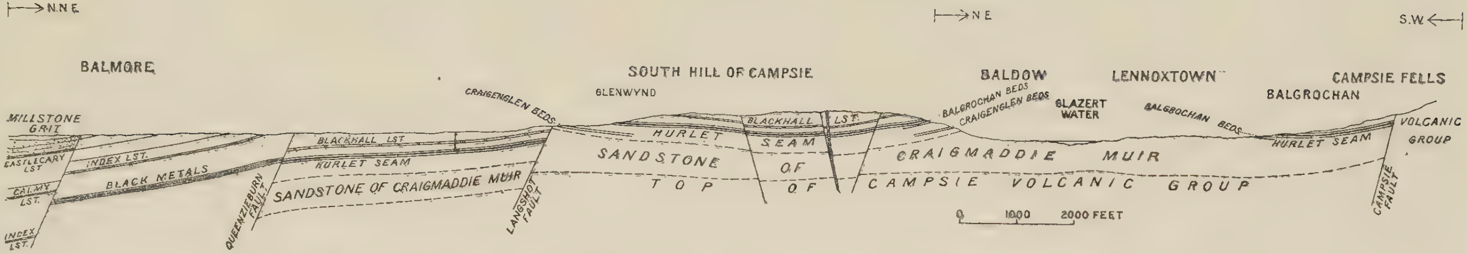

Fig. 10.—Section from Balmore, across the South Hill of Campsie to the Campsie Fault.

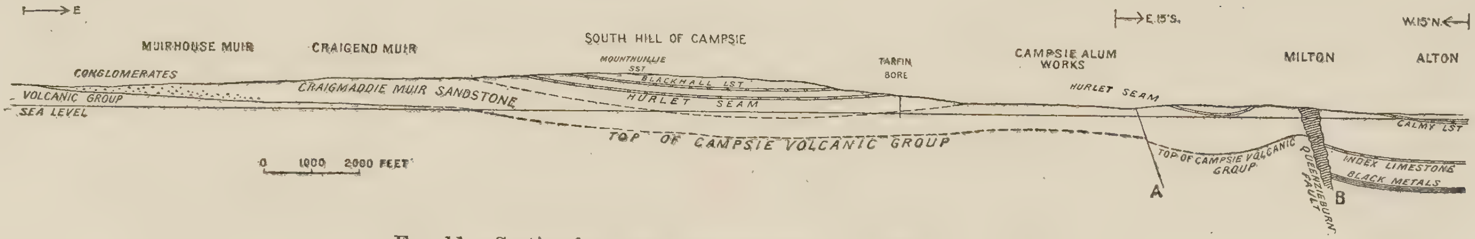

Fig. 11.—Section from east to west across the South Hill of Campsie.

The whole country between Torrance of Campsie and Cumbernauld has been folded along one or more axes having a general trend between north and east. The folding has been comparatively gentle except between Kirkintilloch, Kilsyth, and Banton, where it has been sufficiently intense to bring the Limestone Coal Group up,[1] and the Millstone Grit down, in the midst of an area mostly occupied at the surface by rocks belonging to the Upper Limestone Group. The massive dolerite sill which underlies most of this region is here brought to the surface, and stands out boldly above the surrounding country, and the folding of the sediments is clearly exhibited in natural sections.

The chief anticline begins so far as is known as a gentle dome beneath Kirkintilloch, and is first visible on the map near Solsgirth; its north-western limb is however practically replaced by the St. Flanan fault from here to where the Haughrigg Coal outcrops beneath the sill, half a mile W. of West Board. Leaving the St. Flanan fault (p. 209) the anticline abruptly recommences as a steep sided ridge running N.N.E. to the Roman Station (Fig. 12). This is the beginning of the "Riggin" proper—the old local name for the Kilsyth anticlinal fold. After a slight bend to N.E. the axis divides into two branches, with a subsidiary basin between them, producing the two little anticlines in the Banton Blackband Ironstone near Strone. The western branch appears to die out at once, but the eastern persists across two faults into a group of small ridges found in the coal workings under the sill a short distance north of the alluvium of the River Kelvin (Fig. 13). To the east of this branch, and separated from it by a shallow basin at Auchinstarry, lies another ridge, which appears in the form of a gentle dome near Nether Croy, but on crossing the fault to the north continues as a well-marked anticlinal axis, on the flanks of which the Kilsyth Coking Coal outcrops for a distance of over a mile north-eastwards from the Canal to Townhead, beyond which it persists for 1¼ miles farther to the large east-and-west fault north of Low Banton.

On the flanks of this main anticline, with its branches, are two complementary syclines. The western can be traced from Shirva, where it is so deep that an outlying patch of Millstone Grit appears in its centre, west of Twechar and by Gavell House and Dumbreck to the northern branch of the Queenzieburn fault W. of Balmalloch. North of this fault it seems to die out and to be replaced by a more easterly syncline which reveals itself on the map as a basin of Index Limestone, north of the Townhead Reservoir, bounded on the north by the large east-and-west fault already referred to, beyond which the main syncline is again shifted eastwards beneath the hamlet of Banton. The synclinal structure on the east of the Riggin first appears near Drumbreck, 2 miles E. of Kirkintilloch, whence it runs E.N.E. near Drum Mains and shows as a small basin of the Calmy Limestone near Balloch; turning then to N.E. it becomes more marked at Airdriehead and can be traced N. of Cumbernauld to Castlecary Station.

Each of these synclines flanking the Riggin is itself flanked by more or less clearly marked outer folds. West of the Shirva syncline an anticline runs north-eastwards from Inchbelly to north of Queenzieburn, where it brings up the Index Limestone with the immediately underlying dolerite sill, and thence across the fault with some easterly shift into the ridge known in the Kilsyth Coking Coal near Braehouse (Fig. 13). West of this anticline there are clear traces of a basin around Birdston. Similarly on the south-east flank of the Drumbreck-

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[1] Hence the early exploitation of the mineral wealth of this particular area.

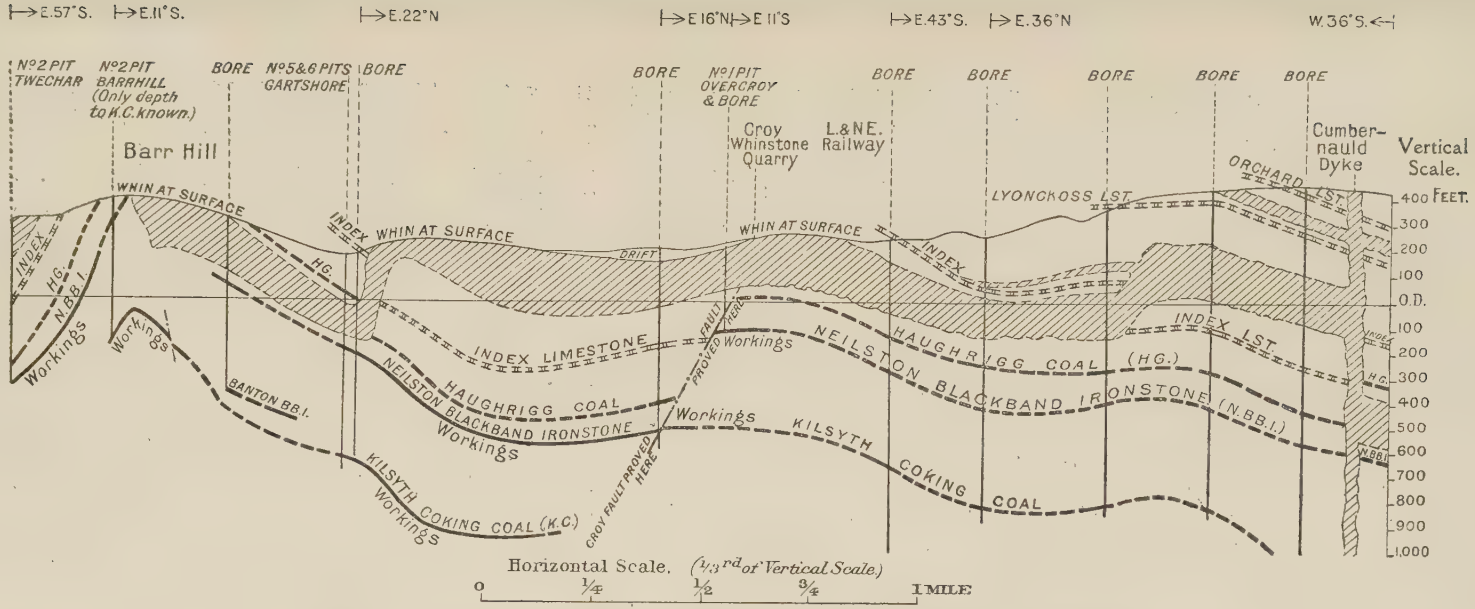

FIG. 12.—Section from Twechar to Auchinbee, crossing the "Riggin" at Barr Hill.

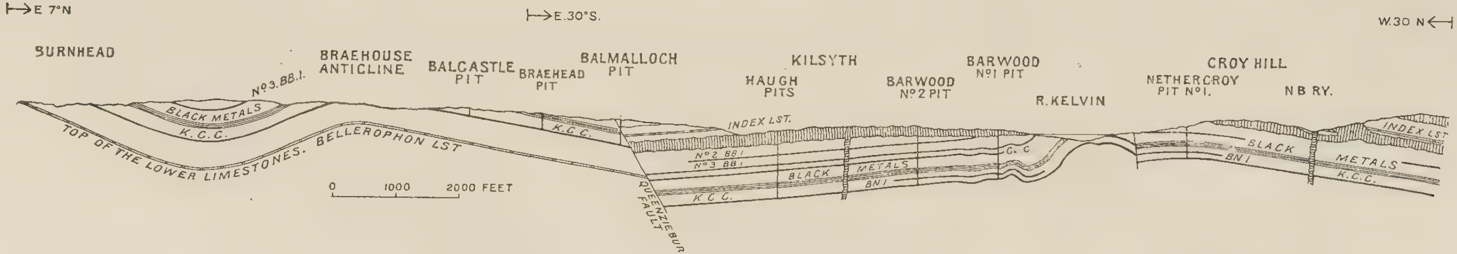

FIG. 13.—Section across the "Riggin" from Croy Hill to Kilsyth and thence north-west across the Braehouse Anticline. BB.I.=Blackband Ironstone; BN.I.=Banton Ironstone; CL.C.=Cloven Coal; K.C.C.=Kilsyth Coking Coal.

Castlecary syncline a distinct axial ridge runs along the Glasgow-Stirling main road, as shown by the outcrops of the Calmy Limestone at Cumbernauld.

Attention may be called to the fact that while the trend of its component anticlines is often distinctly N.N.E., that of the Riggin as a whole is somewhat east of N.E. This effect, as will have been gathered from the foregoing account, is at least partly due to successive displacement of the belt of maximum folding laterally, from one anticline to its eastern neighbour, as the Riggin is traced from south to north.

The western limbs of the main anticlinal fold are found to be in general steeper than the eastern: the north-westerly dip reaches 45° or 50° to the south-east of Twechar (Fig. 12), and 45° to 80° or more north of Nethercroy Pits, where the dip in the opposite direction was 27°. South of Townhead Reservoir where the north-westerly dips are 19° to 27°, the south-easterly are 11° to 15°. The subsidiary anticlines met with in the workings beneath the sill S.E. of Kilsyth exhibit the same differences.

The relation of the folding of the Riggin to the faults which cross it and are described in the following chapter (pp. 208-9) is of considerable interest. Their direction is more or less east and west outside the area of maximum folding, on approaching which they show some tendency to deflection, either transverse to the axis and so parallel to the line of greatest relative tension (*see* p. 207), as in the Arnbrae-Nethercroy and Gavell faults, or parallel to, and with the upthrow side towards, the anticlinal ridge, as at the west end of the Croy fault and the N.N.E. branch of the St. Flanan fault. The manner in which the Gavell, Croy, main Queenzieburn (Balmalloch) and St. Flanan fractures diminish, or even die out, on nearing the same axis seems again an indication of close connection with it; and it is difficult to avoid the conclusion that none of these faults are earlier than the folding, and that those last mentioned are partially contemporaneous with, and due to inequalities of pressure in, the movements which created the Riggin anticline.

The relations of folding and faulting to the dolerite intrusions of this area are dealt with in Chapter VIII.

Two of the sections (Figs. 13 and 14) cross the Riggin from north-west to south-east at different points along the crest of the fold (*see also* Fig. 12). A third (Fig. 15) extends northward across the centre of the Shirva basin, and is supplementary to the other two.

The section illustrated by Fig. 13 expresses the large amount of downthrow to south (150 fms.), of the Queenzieburn fault, already referred to, and shows clearly that the outcrop of higher horizons, as we pass southwards from the Campsie fault is chiefly due to faulting. The Kilsyth Coking Coal occupies a trough between Burnhead and Braehouse, but has been removed by denudation from the summit of the Braehouse anticline. Beyond the Queenzieburn fault the denudation of the Riggin has brought the Kilsyth Coking Coal near the surface. The folding is here much gentler than further south (*cf.* Fig. 14), but a series of minor arches and troughs, which have been met with in the coal-workings, are shown in the section.

Fig. 14 shows the double fold at Auchinvole, and like Fig. 13 indicates the greater steepness of the north-western limbs of the folds. The highest members of the Dumbreck-Shirva syncline are here the beds a short distance above the Chapelgreen Coal (*cf.* Fig. 15).

The principal feature in Fig. 15 is the powerful St. Flanan fault, with a downthrow to north of 300 fms., which truncates and

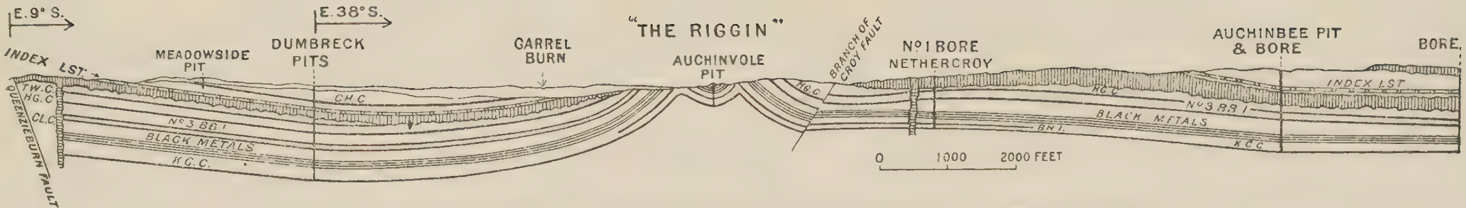

FIG. 14.—Section across the "Riggin" from near Auchinbee to the Queenzieburn Fault.

CH.C. = Chapelgreen Coal; TW.C. = Twechar Coal; HG.C. = Haughrigg Coal; CL.C. = Cloven; K.C.C. = Kilsyth Coking Coal; BB.I. = Blackband Ironstone; BN.I. = Banton Blackband Ironstone.

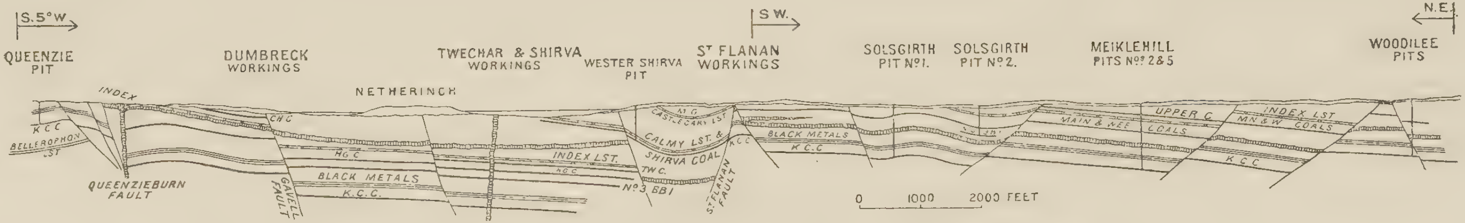

FIG. 15.—Section from Woodilee across the St Flanan Basin to the Queenzie Pit.

M.G. = Millstone Grit; CH.C. = Chapelgreen Coal; TW.C. = Twechar Coal; MN.C. = Main Coal; W.C. = Wee Coal; HG.C. = Haughrigg Coal; K.C.C. = Kilsyth Coking Coal; BB.I. = Blackband Ironstone.

partly replaces the north-west limb of the Riggin anticline, the south-east limb alone remaining, between Solsgirth and West Board. The strata on this limb of the fold are shown in the section to the south of the St. Flanan fault, the beds being twice repeated in the Kirkintilloch district by low-angled faults throwing down to the north-east. C. B. C., C. H. D.

Glasgow and Chryston Areas.

Fig. 16 gives a horizontal section of the ground from Glasgow Green across the eastern part of the City to the Luggie Water at Lenzie.

The dominant feature in the geological structure of the central and eastern portions of Glasgow is the anticlinal fold whose axis runs approximately from west to east through St. Rollox, Blochairn and Riddrie Park. The pitch, or dip of the axis of the fold, is to the east, so that in passing westwards from Ruchazie we find that the beds, from the Virgin and Splint Seams in the Coal Measures to the base of the Millstone Grit, together with the associated teschenitic sills, are thrown off in descending sequence on either side of the fold. The northern limb of the fold is truncated by the Comedie fault, an east-and-west dislocation with a downthrow to the south, by which the Coal Measures and Millstone Grit are brought down against the upper part of the Carboniferous Limestone Series. About a mile to the north is another powerful dislocation, the Garnkirk fault, with a downthrow to the south of about 40 fms.

The Carboniferous Limestone strata which occupy the ground between the Garnkirk fault and the Luggie Water, are arranged in a series of gentle undulations which are traversed by successive faults with, generally, an east-and-west trend and a southerly downthrow. This gently plicated structure and the repeated truncation of the folds by faults, prevent the outcrop of any beds much above or below the position of the Calmy Limestone over a wide area.

Fig. 17 Section from Cardowan, by Garnkirk and Chryston, to the Luggie Water.

The Comedie fault, which forms the northern boundary of the Shettleston and Coatbridge Coal Measures area throws down strata lying slightly above the Virgin Coal against the higher part of the Upper Limestone Group to the west of Gartloch, and against the Millstone Grit further to the east. On the upthrow side of the fault lies the Garnkirk syncline, the centre of this shallow basin being occupied by the sandstones and fireclays of the Millstone Grit. The syncline is cut off immediately to the north of Garnkirk by the Garnkirk fault. The ground northwards from this fault to the Luggie Water is entirely occupied by rocks of the Upper Limestone Group disposed in gentle domes and basins. An inlier of the Calmy Limestone comes to the surface around one of these domes at Chryston village. L. W. H.

Western Area.

A more or less anticlinal area exists to the west of Glasgow. This extends from near Govan in a north-westerly direction towards Clydebank, and was referred to in a previous edition of this memoir as the Govan anticline. The ground is, however, much complicated by faulting. This area is bounded to the south by the Arden basin

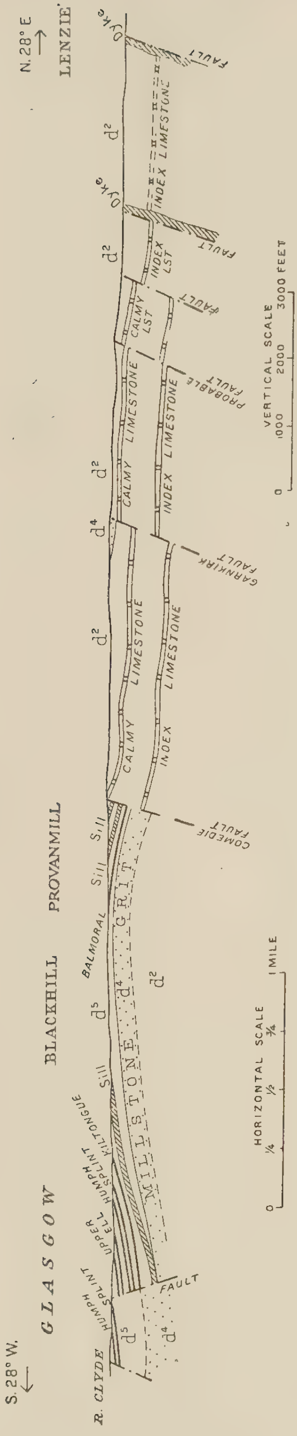

FIG. 16.—Section from the Clyde across the east end of Glasgow to Lenzie.

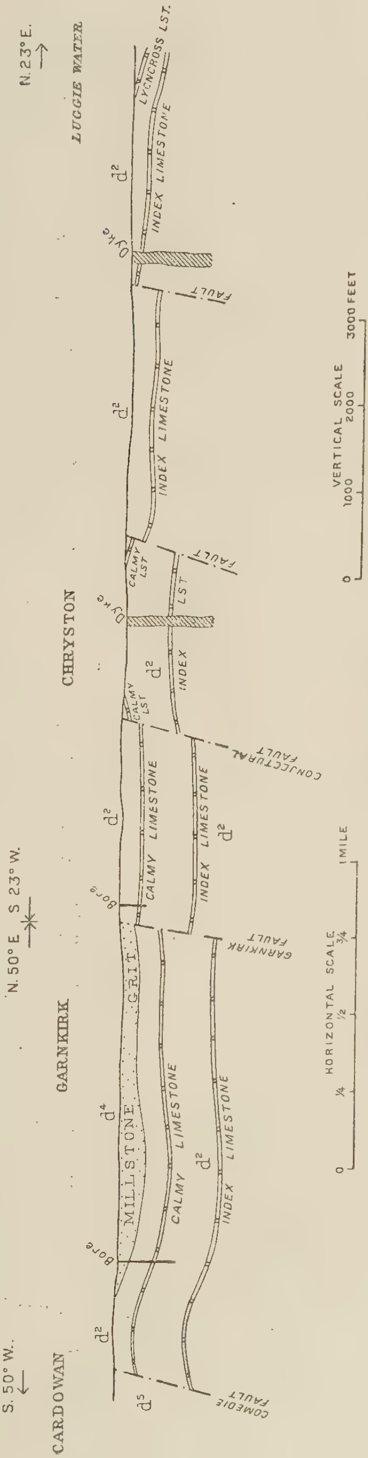

FIG. 17.—Section across the Garnkirk Basin to the Luggie Water.

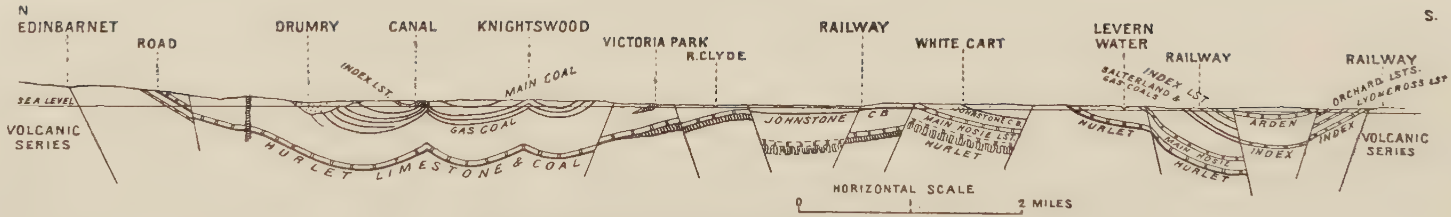

FIG. 18.—Section across the Western District.

(*see* p. 203), and higher beds also occur to the north, near Killermont and Drumchapel.

The structure of the ground concealed beneath the Clyde alluvium is difficult to unravel, almost the only available evidence being supplied by bores, while it is further complicated by the presence of several large faults. It seems clear, however, that the strata between Govan and Renfrew may be referred both to the Lower Limestone Group and to the lower division of the Limestone Coal Group of the Carboniferous Limestone Series. To the south-east of Renfrew, rocks of Calciferous Sandstone age may even be present, bores betwen Deanfield and Braehead having proved a sequence of strata not known above the Hurlet Seam.

Valuable evidence as to the structure of the ground east of Renfrew was supplied some years ago by a number of bores sunk by the Clyde Trust in connection with the proposed new dock between Elderslie House and the Clyde. The general supposition that the " whinstone " rock upon which Elderslie House is built is a continuation of that found close by in the river bed[1] has not been supported by the boring evidence, the only rock met with between these two exposures being blaes, while the dip of the whinstone in the river is to the north-east. It is possible that a fault may separate the two exposures, but further evidence, obtained higher up and on either side of the Clyde, points more to the conclusion that the dolerite in the river-bed represents the small sill usually found between the Blackhall and Hosie Limestones west of Glasgow, while the Elderslie House rock is on a lower horizon and forms part of the Hurlet sill. On the whole it seems probable that the strata here met with belong to the Lower Limestone Group and that a large fault runs in a north-westerly direction on the south side of Elderslie House.

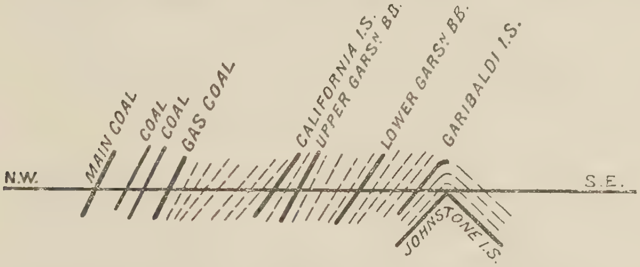

FIG. 19.—Mine Section in Blairdardie Pit (dips to true scale).

The structure of the coalfield at Blairdardie affords some points of interest. An abrupt anticlinal fold, with a north-east and south-west axis, is found east of the canal, and was proved in a stone mine driven from the old Blairdardie Pit. For the details of this section, given below (Fig. 19), we are indebted to Messrs. Wm. Dixon and Co.

The eastern limb of this fold was met with in the Cowdenhill Pits, where the Main Coal was inclined at 45° to the south-east. A small quarry close to the canal, a third of a mile west of Cowdenhill, shows pebbly sandstone dipping at 50° to the north-west, this being the only surface indication within the area covered by the Glasgow Sheet of the existence of this curious line of disturbance.[2]

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[1] R. Craig, ' On a Bed of Dolerite that crosses Renfrewshire,' *Trans. Geol. Soc. Glasg.*, vol. v., 1877, p. 274.

[2] For its remarkable continuation into the Paisley district see ' Economic Geology of the Central Coalfield,' Area IV., *Mem. Geol. Surv.*, 1920, pp. 45-47.

Another sharp fold, also running in a north-easterly direction, is found further south between Hurlet and Barrhead. This is, however—according to Mr. James M'Creath—a monoclinal fold dipping to the south-east, and the dislocation of the strata is so great that a fault is probably also present. The exact nature of this "trouble" has not been ascertained, for, on approaching the line of disturbance, the beds in the Ironstone workings on either side were found to be so highly inclined that they were abandoned. R. G. C.

Southern Area—Pollokshaws and the Cathkin Hills.

The great Dechmont fault which crosses the southern portion of the Glasgow Sheet is fully discussed in Chaper X., and it will be sufficient here to call attention to the fact that along the greater part of its course it brings Coal Measures into juxtaposition with strata on a much lower geological horizon. The region on the upthrow, or south-western side, may be divided into two main structural areas :—

(i) The area of volcanic rocks forming the Cathkin Hills.

(ii) The area to the west, occupied mainly by strata of the Carboniferous Limestone Series.

(i) The Cathkin Hills form a high-level area which may be regarded as a "*horst*" or elevated fault-block, since it is bounded on almost every side by faults whose downthrow is outwards—away from the area of volcanic rock. Its present elevation above the surrounding country, which is most marked along the northern margin of the area, is, however, due to the superior resisting powers of the basaltic rocks of which these hills are composed.

On the eastern and part of the northern side the area is limited by the Dechmont fault, to which reference has already been made. The remainder of the northern boundary is also a fault with a downthrow to the north, which probably intersects a similar fault forming the margin to the west. On the southern side there are places where an unbroken succession from the volcanics into the overlying strata of Calciferous Sandstone age can be observed. Elsewhere, however, along this margin the boundary is a faulted one, though the faults are probably of no great magnitude.

Along the northern edge the ground falls away everywhere towards the faulted boundary, while the sheets of lava are inclined gently to the south. As a result, the lower group of microporphyritic basalts comes to the surface along this margin, while the overlying group of more conspicuously porphyritic type appears higher up the hill slopes, and forms much of the plateau to the south. South of Muir there is an area of microporphyritic basalts of Dalmeny type, which much resemble those of the northern face. It is not certain whether these are an intercalation in the higher series, or are lower beds brought up on a dome-shaped flexure. The structure of this part of the area is somewhat obscure, but there is evidence that the detrital grits and conglomerates to the south-west of Carmunnock overlie the upper or porphyritic series of basalts, while at Thorntonhall, beyond the limits of the map, they are overlain by limestone.

(ii) The most noticeable structural feature in the area lying to the west is the elongated pericline known as the Arden basin, which extends in an easterly or east-south-easterly direction from Barrhead to the

White Cart, a little to the north of Clarkston. It is bounded on the south by a large upthrow fault which brings in volcanic rocks belonging to the same general horizon as those of the Cathkin Hills. On the other sides its limits are not so clearly defined. To the north-east the inward or southerly dip extends in one place, in spite of minor faulting, as far as the Dechmont fault at Strathbungo. The northern margin of the basin is bordered by an irregular area of the underlying Limestone Coal Group, but the central region is entirely occupied by the Upper Limestone Group, including strata ranging from the Cowglen or Index Limestone to some distance above the Arden or Calmy Limestone. Two separate patches of the rocks above the latter horizon occur near the centre of the basin ; one round Davieland, and a larger one reaching from Barrhead to near Thornliebank.

Fig. 20 represents a horizontal section across the basin, from a point a short distance south of Davieland to Pollokshields. Starting from the volcanic rocks, the fault is crossed, and an ascending series passed as far as Davieland. Beyond that point the sequence is again traversed in descending order. A fault with downthrow to the north-east causes the Lyoncross Limestone to crop a second time to the north of Hillhead. The massive sandstone which corresponds to the Barrhead Grit then comes to the surface, and forms the foundation on which much of the town of Pollokshaws is built. The section also shows the Limestone Coal Group underlying the Upper Limestones to the north, while it is brought against the base of the Coal Measures by the Dechmont fault in the neighbourhood of Pollokshields.

Reference has already been made in a former chapter to the work done by the late Captain Stewart of Williamwood in unravelling the structure of this district. His paper on the limestones, read in the year 1881,[1] was accompanied by a geological map of the eastern half of the Arden basin, which added greatly to the previous knowledge of this area. In this map the author traced the outcrop of the Orchard Limestone round the eastern end of the basin, and showed how both this limestone and the Lyoncross have extended outcrops on the southern side. The main features of his mapping have been embodied in the present Sheet, and the officers of the Survey wish to express their indebtedness to him, not only in this respect, but also for personal help and the communication of a large number of bore journals.

It is probable that the Index Limestone, as well as the two higher limestones last mentioned, occurs on the south side of the basin, but only in the vicinity of Cleuch farmhouse. Elsewhere along this margin its outcrop is cut out by the fault. It appears, however, close to the White Cart near the Overlee viaduct, where the overlying Barrhead Grit can also be observed. The outcrop of the limestone lies to the west of the White Cart for some distance to the north. A thin sill of teschenitic dolerite makes its appearance a short distance underneath, and thickens out in this direction. Just south of Linn House both limestone and igneous rock must be affected by a fault which is probably a continuation of the one already referred to as duplicating the outcrop of the Lyoncross Limestone in the section (Fig. 20). As a result, the outcrops cross the river, and the sill of dolerite gives rise to a slight waterfall.

Further north the sill is affected by another fault with a north-eastern downthrow, and it is possibly due to the continuation of this

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[1] 'Notes on the Limestones in the Parishes of Cathcart and Eastwood, Renfrewshire,' *Trans. Geol. Soc. Glasg.*, vol. vii., part i., 1883, p. 158.

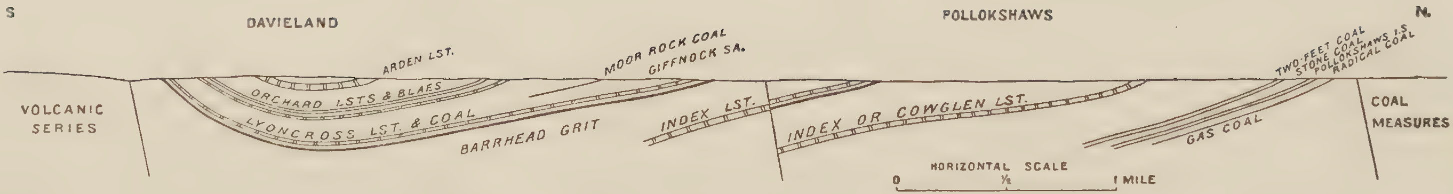

FIG. 20.—Section across the Arden basin, from near Holm to Pollokshields.

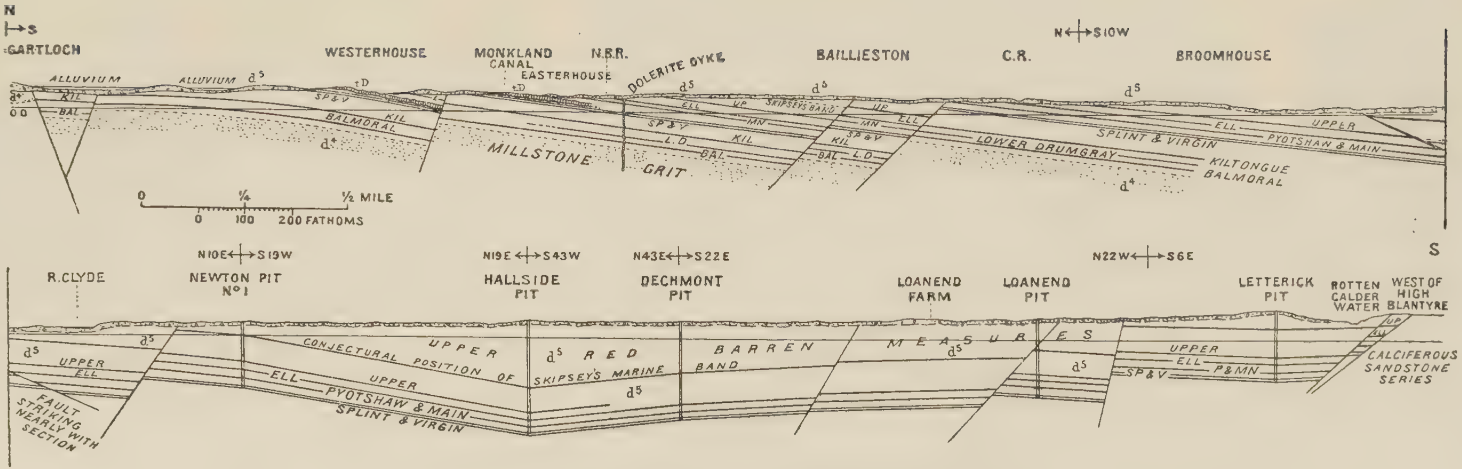

FIG. 21.—Section from near Gartloch to near High Blantyre.

dislocation that the Lyoncross Limestone and Coal are brought into the positions which they were found to occupy at Millbrae Bridge, south of Langside, during the operations in connection with the White Cart purification scheme. The course of this fault as shown on the map is, however, somewhat conjectural. A moderately large fault, as already pointed out by Captain Stewart, must run in a northerly direction to the west of Pollokshaws. E. M. A.

Shettleston and Uddingston District.

The section in Fig. 21 has been drawn to illustrate the structure of this district. It proceeds in a general southerly direction from the large east-and-west fault—the Comedie fault—which at Gartloch forms the northern limit of the Coal Measures. Thence it passes by Broomhouse to Hallside pit, which is the deepest pit in Lanarkshire (1477 ft.), and lies in the centre of the Uddingston basin.

The general structure in the northern part of the area near Shettleston and Baillieston is extremely simple. North of the Monkland Canal the beds are somewhat undulating, but, broadly speaking, dip to the south. Close to the canal, and southwards to the Clyde, the dip is more uniformly south, but its effect is to some extent counterbalanced by two large east-and-west faults with downthrow to the north. The more southern of these faults has in places a throw of nearly 100 fms., and is described, under the name of the Shettleston fault, in Chapter X. The southerly dip continues, and at Hallside Pit the section crosses the deepest part of the Uddingston basin. On the north side of the basin the seams generally dip to the south, at angles varying from 5° to 10°. On the south side the dip is more variable. The coals dip steeply away from the Dechmont fault (*see* p. 211), which bounds the basin to the south-west, bringing Barren Red Measures against lavas and sediments of the Calciferous Sandstone Series. This fault is encountered by the line of section so obliquely that the dip of the strata away from it is not apparent. J. S. G.W., W. B. W.

CHAPTER X.

FAULTS.

As in other Scottish Carboniferous areas, the faults in the Glasgow district are mainly normal in character. A glance at the map will show that these do not run with equal frequency in all directions of the compass. A large proportion of them have an east-and-west trend, while many run north-west and south-east. Although faults with an intermediate direction may be found, these two classes are probably distinct. There are also smaller numbers of faults running in many other directions.

The east-and-west faults may be again subdivided into those with a southern hade and downthrow, and those having hade and downthrow to the north. Similarly the N.W.-S.E. faults throw some to the north-east, and others to the south-west. Dynamical considerations show that it is likely that the two classes of east-and-west faults were formed under the same conditions of stress, at a time when there must have been a tension, or at least a relief of pressure, from north to south. In the same way the two classes of north-west faults were most likely formed simultaneously under a tension or a relief of pressure from south-west to north-east, and must, as a system, be either earlier or later than those which run east and west.[1]

Of the east-and-west dislocations the most important is the Campsie fault, which forms the southern boundary of the Campsie Fells and runs entirely across the map with a downthrow to the south. From the western boundary of the Sheet as far as Blanefield it brings the volcanic rocks of the Kilpatrick Hills into contact with Upper Old Red Sandstone to the north. Actual sections of the fault along this part of its course are nowhere visible, but the shattered volcanic rocks are well seen on the slope south of Dumgoyach, where they have been reduced to a crush conglomerate in a narrow strip to the south of the fault. Boulders of basalt, nearly a foot in diameter, are embedded in a more finely divided matrix of the same material, and the rock bears a remarkable resemblance to a volcanic agglomerate. It shows, however, no tendency to occur as a bed, and its relation to the fault can hardly be accidental.

Near Blanefield Print Works a branch from the main fault runs obliquely up the hillside to the E.N.E. It starts with a downthrow to the S.S.E. of about 800 ft., but a mile further on this has dimished to about 100 ft. In the angle between the two a wedge-shaped mass has been drawn downwards by the great subsidence which was proceeding to the south. The steady westward dip of the lavas, due to the sagging of the wedge, can readily be recognized from a distance by the configuration of the ground.

From Strathblane to beyond the Clachan of Campsie the main fault brings the porphyritic basalts of the upper portion of the volcanic series into contact either with the underlying division of non-porphyritic basalts, or with the sediments of the Cementstone group upon which the latter repose. Eastwards, the sediments which overlie the volcanic series occur on the south side, and are brought against the lavas on the north. In this part of its course the fault coincides with a line of bold escarpment, which forms a part of the southern boundary of the Campsie Hills, and is due to the superior resistant quality of the traps on the upthrow side. Opposite Lairs the lower portion of the volcanic series is thrown against beds a little above the Hurlet Limestone. South of Cort-ma-Law the fault divides into two branches. Opposite Brown Hill it is possible that these may reunite, but, if so, another split takes place immediately to the east. In this case the two parts diverge somewhat widely, and a thick series of ashes and sediments comes in between. These dip to the east, so as gradually to increase the throw of the northern branch. South of Laird's Hill the latter makes a very remarkable Z-shaped bend, altering its trend suddenly from somewhat north of east to a little to the west of south, and after about half a mile resuming its original direction. Near the Garrel Burn, on the eastern margin of the Glasgow Sheet, the throw of the fault attains its maximum, the Old Red Sandstone on the northern side being brought against a horizon about 70 fms. above the Coking Coal, indicating a displacement of probably not much under 500 fms. The fault continues in an E.N.E. direction, with diminishing throw, to beyond Dunipace.

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[1] Particular N.W. faults may have been formed at other periods. *See* the description of the faults near Kilsyth, below, and p. 213, footnote.

Attention should be called to the difference in the amount of folding which has taken place on the two sides of this fault. On the north, the sedimentary series and the volcanic series of the Campsie Hills are practically horizontal, while, on the southern side, the lavas of the Kilpatrick Hills and the sediments further to the east are thrown into many minor undulations. Hence it may be assumed that certain of the folding movements of the district took place contemporaneously with the formation of this line of fault. E. M. A.

The faults which affect the anticline of the Riggin, near Kilsyth (p. 196), may next be considered.

The name Queenzieburn fault[1] has been given to the large fault which like the Campsie fault has a southerly downthrow and runs entirely across the Glasgow District Map from west to east. At the western margin it throws the Craigmaddie Sandstones against the volcanic traps, but soon passes entirely into the sediments. As far as Barnellan, its course is nearly due east, but from this point to a little beyond Milton the chief dislocation appears to be more nearly north-east, though the country north-west of Kirkintilloch is not sufficiently well explored to make it certain that there is no easterly branch. At Milton its throw is between 350 and 400 fms. The fault again turns east and passes north of Queenzieburn where it splits into two branches. The northern or Balmalloch branch has a throw of about 150 fms., and in places an almost vertical hade; its trend, at first slightly north of east, deviates north of Kilsyth to E.S.E., and its throw is known to decrease rapidly and to die out before reaching the main "Riggin" axis (p. 194) near Woodend; it does not appear again on the other side of the anticline. The southern or Arnbrae-Nethercroy branch starts with a small throw, perhaps only 9 fms., and at first appears to flank the Dullatur dolerite dyke (p. 156), but its surface position soon diverges north from this to Arnbrae, where its throw is about 25 fms.: the position in the Kilsyth Coking Coal is south of the dyke and can be traced eastwards and then south-eastwards to Kilsyth Hospital, where the throw is 35 fms. and still increasing; beyond this point the fault appears to cross the parallel anticlines of the Riggin, probably with varying throw reaching locally 50 fms., and is 23 fms. where next met with at Nethercroy Coal Pits. Here it passes beneath the sill and is found again with a throw of 35 to 40 fms. near Dullatur, whence it probably runs eastwards for two or three miles, with throws reaching 100 fms.

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[1] 'B' in Fig. 11; shown also in Figs. 10, 13, 14, and 15. The Langshot fault (Fig. 10) is a branch of the Queenzieburn fault which runs along the southern face of the South Brae of Campsie.

The Gavell-Croy faults cross the Riggin further south. The fault at Gavell runs E. by S. and is at first 40 fms. down to south, but is known to be only half that figure across the canal, where its direction is frankly S.E. So far as is known, the dislocation dies out soon after, or possibly even before, meeting the outcrop of the sill, but a few hundred yards further the Croy fault begins on the axis of the Riggin and runs E.N.E. with rapidly increasing throw, passes beneath the sill, where it is joined by a smaller fault coming from the N.N.W., and continuing under the dolerite, as known from mineral workings (Fig. 12), reappears at the surface at Croy Station with a throw of 60 fms. Its further continuation is unproved.

The next fault to south is the St. Flanan "Dyke" (Fig. 15), which unlike those previously described throws down to north. This imporant dislocation begins somewhere north of Kirkintilloch, and increases to about 300 fms. at St. Flanan Coal Pits, where its inclination is known to be about 67° from the horizontal, and its direction E.N.E.—nearly parallel to the axis of the gentle dome around Solsgirth. Its trend then curves gently to east and becomes distinctly transverse to the strike of the strata on its northern side; owing to their steep westerly dip, and to a branch which leaves it in a N.N.E. direction, its throw rapidly diminishes and probably reaches a minimum where the main Riggin axis crosses to its northern side, near West Board, but increases again further on, since the strata on its northern side are dipping eastwards away from the Riggin while on the south the dip is almost at right angles to the fault. The fault passes under the sill, as proved in underground workings, and dies out a short distance beyond East Board.

An interesting feature of the Kilsyth district is the unusually low hade of certain faults near the ends of the Riggin axis. The three faults between Gartshore House and West Board all have inclinations of less than 45° to the horizon, while that of the fault between Colzium House and Riskend, N.E. of Kilsyth, has been proved at one point to be horizontal, and even slightly reversed. All of these faults have a direction between south and east, and more or less transverse to the anticlinal axis. C. H. D.

A large N.W. fault diverges from very close to the Queenzieburn fault near Barnellan, and has a downthrow to the south-west of about 140 fms.[1]

The Cadder fault starts from near the Queenzieburn fault in the neighbourhood of Milngavie, and runs across the Cadder ironstone field by Buchley—where its throw to S.W. is from 30 to 50 fms.—and the Wilderness Plantation. The east-and-west fault that passes to the north of Bishopbriggs has a downthrow to the south, and is probably the same as that which runs east from Lenzie. It is accompanied from that locality to near Gartferry Mains by a quartz-dolerite dyke. If the above supposition is correct, the dyke diverges from the fault on both sides of this tract, maintaining an almost straight course, while that of the fault is somewhat curved.

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[1] Shown at south end of Fig. 10.

The Garnkirk fault (Figs. 16, 17), another powerful dislocation, with downthrow to south of 40 to 90 fms., runs parallel to the last at a distance of about a mile and a half. From Lochend House to near Robroyston it throws the Millstone Grit against the Carboniferous Limestone Series ; westwards it lies entirely within the latter formation. Near Ashfield it is cut by a quartz-dolerite dyke, running a little to the north of east, which is unaffected by, and is clearly later than, the fault (*see* p. 158). The fault has a downthrow of 90 fms. opposite Garscube House, at which point it bends to the north-west and continues in this direction beyond Bearsden, where it dies out.[1]

The name Comedie fault (Figs. 16, 17), has been given to the powerful dislocation[1] which runs almost due east from south of Maryhill, and may extend, but with diminished throw, as far as Woodend Loch. The downthrow to the south increases from 11 fms. near Ruchill to about 200 fms. at Comedie, a little to the east of Hogganfield Loch, where it brings Coal Measures slightly above the Virgin Coal against strata near the position of the Calmy Limestone. Eastwards the workable coal seams are brought against the Millstone Grit, and the fault dies out about the edge of the Sheet. E.M.A.

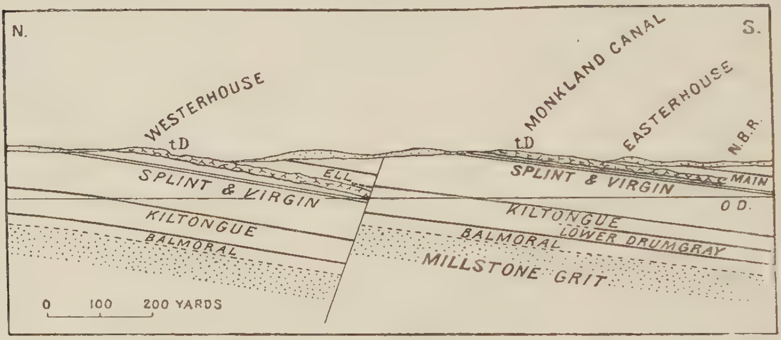

Fig. 22.—Section showing the relation of the Westerhouse Teschenite Sill (tD) to an east-and-west fault. To the north of the fault the whin probably occupies the position of the Main Coal.

A sill of teschenite is distinctly displaced by an east-and-west fault at Westerhouse, north of Baillieston. The throw of the fault is about 50 or 60 fms., and though the sill is only 7 or 8 fms. in thickness, it occupies exactly the same level with regard to the coal seams on the two sides of the fault. It seems impossible that this could have arisen otherwise than by displacement. (Fig. 22.)

The Shettleston fault (Fig. 21), also known as the Mount Vernon fault, enters the map to the east of Baillieston, where it has a low inclination, its position in the Kiltongue Coal being 400 ft. further south than that in the Main, although these seams are only 350 ft. apart. The fault passes south of Baillieston and Shettleston, bringing Barren Red Measures on the north against the Productive Measures on its southern side. East of Parkhead the downthrow to the north is 100 fms., but from this point rapidly diminishes to the west. The course of the fault beyond Gallowgate is not known. W. B. W.

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[1] The Garnkirk and Comedie faults have been connected with the Glasgow Earthquake of Dec. 14th 1910, by Prof. J. W. Gregory, *Trans. Inst. Min. Eng.*, vol. xli., part i., 1911, 55-63, and *Trans. Geol. Soc. Glasg.*, vol. xiv., part ii., 1911, pp. 89-114.

Several other east-and-west faults enter the city area on the east, north of the Clyde, and cross Glasgow Green, their course to the west being in most cases concealed beneath the river alluvium. They all throw down to the south, but in no case is the displacement large. One, with a southerly downthrow of about 50 fms., runs a little to the north of London Road, and was formerly known as "David Dale's Dyke." Another appears to cross the Clyde, and to cause a large amount of displacement near Pollokshields. The western part of this fault, however, is inferred from bore sections, and has not actually been proved.

The dolerite dykes striking W.N.W., of which several examples occur in the south-eastern portion of the Glasgow Sheet, are believed to be of Tertiary age. In Ellismuir No. 3 Pit, south-east of Baillieston, there is a good exposure of two dykes of this class. The more southerly of the two is accompanied by a fault with a downthrow of 10 ft. to the north, and is distinctly crushed in its interior along a plane inclined in the direction of throw. This dyke is also seen to be crushed by a fault which follows it in Bredisholm Quarry, a little to the south-east. Thin intrusions of uncrushed dolerite seem, however, to occur along a line of fault which runs parallel to this dyke and a little to the south of it in the pit referred to. The bearing of these phenomena on the age of the north-western faults will be discussed in a later paragraph.

Several minor north-and-south faults occur in this part of the Glasgow area. One of these appears, from underground evidence, to shift the Shettleston fault near Baillieston, while on the other hand two others seem to be themselves shifted by the east-and-west fault which runs east from Carmyle to the north of Uddingston.

An east-and-west fault with northerly downthrow occurs to the south of Rutherglen, starting from near the Dechmont fault to the west, and running as far as Cambuslang. Its maximum downthrow is 50 fms., and its hade, as proved from underground workings in various seams, in Stonelaw No. 2 Pit, near Rutherglen, is very steep, being less than 5° from vertical.

The most important of the N.W.-S.E. lines of dislocation is the Dechmont fault,[1] which enters the map in a north-west direction, somewhat to the west of High Blantyre. It there throws strata belonging to the Barren Red Measures against members of the Calciferous Sandstone Series lying above the traps. At Loanend, strata about 100 fms. above the Upper Coal are brought against a position well down in the Volcanic Series, representing a throw of at least 550 fms. Near this point the fault turns suddenly to the west for about three miles, passing Dechmont Hill, and forming the northern boundary of the upland area of the Cathkins. Near Burnside it appears to split. One portion continues in the same direction as far as Castleton, still forming the boundary of the volcanic area, but what is perhaps the larger part turns again to the north-west, and runs by Mount Florida to near Govan. Near Crossmyloof the downthrow must be at least 300 fms. It is unlikely that so large a fault should die out within a couple of miles, and it is possible that it may cross the Clyde and be continuous with the north-westerly fault which runs from near Scotstoun to beyond Yoker.

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[1] *See* Fig. 21.

The sharp bend in the fault at Loanend, and the subsequent change in direction of the main branch near Burnside, may perhaps be explained as follows :—A fault of about 28 fms. downthrow runs past Loanend in a direction a little to the south of east, very nearly in line with the east-and-west portion of the Dechmont fault, and probably, as shown in the map, in direct continuity with the latter. It may therefore be supposed that an east-and-west fault originally crossed the area. On meeting this previously existing fault the north-west one took advantage of it for three miles, greatly increasing the previous amount of throw, and diverging from it where the latter now appears to divide.

A north-west fault, with south-west downthrow amounting in one place to 70 fms., runs from Govan by Shieldhall and Elderslie House to beyond the limits of the map where it reaches 200 fms. and is known as the Blythswood fault. It begins quite close to, and is in line with a part of, the Dechmont fault, of which it was formerly taken to be a continuation. The downthrow, however, is in the opposite direction (*see* Fig. 18).

The Crookston fault,[1] which runs from north of Cowglen House to Blackhall near Paisley, has a downthrow of at least 75 fms. to the north, near Crookston Castle. This fault, and two smaller and roughly parallel faults near Blackhall and to the north of Williamsburgh, all displace the Hurlet teschenite dolerite sill, which appears in the same position with regard to the Hurlet Limestone on the opposite sides of these dislocations.

The east-and-west line of fracture already described as possibly deflecting the Dechmont fault, appears to intersect or to be deflected by a north-east one near Castleton. The latter bounds the traps for some distance to the south-west, bringing them against strata which probably belong to the Limestone Coal Group. It occupies the bed of the White Cart for a short distance beneath Overlee viaduct, south of which it perhaps intersects the great east-and-west fault to be next described. This rupture forms the northern boundary of the area of volcanic rocks which appears along the southern margin of the Glasgow Sheet, and just west of Cleuch throws this series against the Lyoncross Limestone, a downthrow to the north of at least 300 fms. In Auchinback railway cutting, just north of Balgray Reservoir, the position of the fault can be located to within a few feet. At this point, a limestone correlated with the Hurlet Seam (p. 36), is brought against the Index, indicating a throw of about 200 fms. On the west side of the bridge, in this same cutting, a small fault which truncates the Index Limestone terminates abruptly against the base of the Barrhead Grit. There are two alternative explanations. Either the fault is later than the limestone, but earlier than the formation of the grit, which rests upon it with a slight local unconformity, or else thrusting movement has taken place along the base of the grit and carried the upper portion of the fault out of sight. The latter supposition appears to be the more probable.

The Parkhouse fault runs N.E. by Parkhouse as far as Kennishead, with a downthrow of 50 fms. to the south-east at the former locality. Another fault passing through Househillmuir with a more northerly trend, and also throwing to the S.E., meets the Parkhouse fault just west of Barrhead. The Hurlet Coal was found to be turned down towards it on the upthrow and up towards it on the downthrow side, to a greater extent than usual ; the structure might in fact be described as a monoclinal fold with a slight break in the centre.

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[1] This is a continuation of the Newton fault of 'Economic Geology of the Central Coalfield,' Area IV., *Mem. Geol. Surv.*, 1920, p. 5.

In the foregoing description of the various east-and-west faults, it will be noticed that all the largest members of this class in the northern part of the sheet throw to the south, while the Shettleston fault and those to the south of it mostly throw in the opposite direction. There is thus a regular area of subsidence with centre near Shettleston, and a series of step faults throwing towards it on opposite sides. In the western part of the district the structure is not so regular, but the same principle can be recognized.

The evidence obtained with regard to the relative age of the various systems of faults and intrusions may now be summed up. In the first place more than one example has been given of a sill of teschenitic dolerite being clearly thrown by an east-and-west fault, showing that the displacements are of later age than these intrusions. With regard to the quartz-dolerite sills the evidence adduced on another page (p. 155) shows that apparently such is not the case ; the sills are later, or at least not earlier, than the faults of this class.

The facts cited with regard to the Garnkirk fault show that in cases at least an east-and-west quartz-dolerite dyke is later than a fault in the same direction.

From the evidence obtained in and near Bredisholm Quarry it may be argued that the N.W.-S.E. faults are partly earlier and partly later than the N.W. Tertiary dykes. A precisely similar result has been obtained with regard to the system of N.W.-S.E. faults which accompanies the Tertiary dykes of Cowal.[1] It seems in fact possible that the same system of tension, or relief of pressure, which produced the dykes, may under different conditions have produced the faults, which, although not strictly contemporaneous, are all of the same general age. That faults of this class in the Glasgow district are later than at least the east-and-west displacements agrees with the theory advanced to account for the peculiarities of the Dechmont fault, and the same has been proved to be the case in other parts of the Lanarkshire Coalfield.[2] E. M. A.

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[1] 'Geology of Cowal,' *Mem. Geol. Surv.*, 1897, pp. 145-6.

[2] 'Economic Geology of the Central Coalfield,' Area VII., *Mem. Geol. Surv.*, 1920, p. 102 ; *ibid.*, Area IX., 1921, p. 99. In the folded Riggin area faults in these two directions may perhaps be contemporaneous (p. 196) ; the N.W. members may not in this case be Tertiary.

CHAPTER XI.

PLEISTOCENE AND RECENT.

GLACIAL.

A COMPLETE re-examination of the glacial phenomena does not come within the scope of the present revision of the Carboniferous areas of the West of Scotland, this revision having for its primary object the collection of recent information respecting the economic geology of the district.

In the following pages will be found a brief statement of the order of events in the glacial history of the region, followed by descriptions of certain features to which more particular attention has been paid during the progress of the revision.

With regard to the pre-glacial topography of this area, Mr. Carruthers has pointed out the remarkable coincidence of the great pre-glacial valleys of the Kelvin and the Clyde with synclinal folds in the underlying Carboniferous strata. He has further ventured to suggest, as an inference from this fact, that the position and course of these valleys may have been directly determined by the structure.

No attempt, however, will be made to present a complete history of the glaciation of the country, or to describe in detail the Pleistocene deposits of the Clyde valley.

For fuller information on these points the reader is referred to the numerous excellent publications on the glacial geology of the district, and especially to the valuable work of James Smith of Jordanhill,[1] and of Messrs. Crosskey and Robertson, on the Clyde glacial beds.[2]

Many papers bearing on the subject will be found in the Transactions of the Glasgow Geological Society.[3] L. W. H.

The chronological sequence of events in the geological history of the district, before, during, and after the Glacial Period, appears to be as follows :—

(1) Land at least 300 ft. above present level ; development of the pre-glacial topography :

(2) Depression of land almost to present level, accompanied by silting up of the valleys with alluvial deposits :

(3) Advance of the great ice-sheet, first from the north, later from the north-west. Deposition of boulder-clay, incorporated with alluvial sands, etc., along the sites of the old valleys. Drumlin formation, especially to the south and east of Glasgow :

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[1] 'Researches in Newer Pliocene and Post-Tertiary Geology,' Glasgow, 1862, and many other papers whose titles are given in the Appendix.

[2] *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, pp. 45, 267 ; vol. iii., 1871, pp. 113, 321 ; vol. iv., 1874, pp. 32, 128, 241 ; vol. v., 1877, p. 29.

[3] 'History of the Geological Society of Glasgow, 1858-1908,' Glasgow, 1908, ch. viii.

(4) Retreat of the ice-sheet, with special phenomena in the Campsie Fells :

(5) Accumulation of the 100-foot beach deposits with sub-arctic fauna ; ice present towards the mouth of the Clyde :

(6) Complete retreat of ice from the district. Elevation of the land and formation of the 50-foot beach, with more temperate fauna.

(7) Further elevation and subsequent depression of the land, followed by the formation of the 25-foot beach.

(1) PRE-GLACIAL TOPOGRAPHY.

An attempt has been made, in the accompanying topographical map of a part of the Glasgow district (*see* folding Plate at end of volume), to portray the contours of the rock surface, now almost smothered in drift and alluvial deposits. Such an attempt is justified by the multiplication in the number of borings put down in search of minerals, water, etc., during the last hundred years.

The ancient landscape thus revealed is essentially a pre-glacial one. It was formed at a time when the land stood at least 300 ft. higher than it does at present, and must be referred to the late Tertiary period of continental uplift, which affected the whole of the North Atlantic. The valleys differ only from the fiords and sea-lochs of Norway and the British Isles in being filled with drift to the exclusion of the sea.[1]

A general examination of the map shows that the features on the whole are in low relief. The mature erosion thus indicated is especially expressed in the low grade of the valley floors, which have been cut down close to their base level.

Although the general drainage lines are in much the same direction as those now existing, certain features are widely different. Most prominent of all are the three large valleys which converge near Clydebank. Of these the chief is the great " Kelvin " or Bearsden channel, now completely buried in drift. The valley next in importance is only half as deep ; it lies to the west of Paisley, occupying much the same area as that of the Black Cart at the present day. The third, and strangely enough, the shallowest, coincides with what is now the main valley of the district, that of the River Clyde.

Another feature of primary importance is also revealed. This is the long ridge, hereafter termed the *Renfrew Bank*, which runs underneath the alluvial flats near that town.

Several interesting facts are brought out on investigating the relation between these old land forms and the underlying geological structure.

In the first place the broader topographical features are essentially *structural*, the valleys being established along synclines, and the higher ground on anticlines.

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[1] There is an abundant literature relating to the submerged valleys of the continental shelf of Europe and North America, but as yet it has not been found possible to fix an exact geological date either for the formation of the shelf or the period of uplift which brought about its dissection. An elaborate discussion of the evidence to date and an account of the former literature is given by Fridtjof Nansen *in* 'The Norwegian North Polar Expedition, 1893-96, Scientific Results,' vol. iv., 1904, p. 96 *et seq.* *See also* E. Hull, *Trans. Vict. Inst.*, vol xxv., 1896-97, p. 305, etc. ; J. W. Spencer, *Bull. Geol. Soc. Amer.*, vol. ii., 1899, p. 67 ; vol. vi., 1895, p. 111 *et seq.* ; vol. xiv., 1903 ; *Geol. Mag.*, vol. v., 1898, p. 35, and numerous other authors. W. B. W.

The great Bearsden channel is an excellent case in point. The course of this valley lies entirely along the axis of a well-developed synclinal fold that extends from Kilsyth and Kirkintilloch down to Clydebank and Bowling.

Although the relatively hard arenaceous strata of the Upper Limestone Group occupy much of this syncline, and the lower end of the valley cuts across strata of very variable resistance, there is no serious deviation of the course of the valley from this synclinal axis.

Equally noticeable is the coincidence between the line of the Renfrew Bank and that of the "Govan anticline" (*see* p. 198).

A further example of the preponderating influence of structure on topographical development is afforded by the course of the old Clyde valley above Glasgow. In this case, again, the channel runs along a synclinal axis, in spite of the fact that the centre of the fold is occupied by the massive sandstones of the Barren Red Measures, flanked by much softer strata belonging to the Productive Group.

In the development of the old Black Cart Valley, structural and lithological influences are in combination. This depression has been carved out of a broad syncline of soft strata in the Lower Limestone Group, the higher ground to the north being largely occupied by sandstones of Calciferous Sandstone age.

The agreement of hill and valley with anticline and syncline may be only a coincidence, but, taking the facts as a whole, it is difficult to resist the suggestion that the main drainage lines of the area may have been initiated before folding movements had entirely concluded. This supposition does not of necessity imply that the drainage originated on Carboniferous strata alone. It may have begun on later rocks, of whose existence all traces are now lost. But it does involve either a continuation or recrudescence in Tertiary times, of a folding which may have been initiated at a much earlier period.

But while it is evident that the chief features of this ancient topography are structural, evidence is not lacking of modification due to direction of strike and inequalities of hardness in individual strata. Such influences can be clearly traced in the lower part of the old Clyde valley, from Govan to Drumry. Between these points the channel is largely excavated in the soft shaly strata of the Garscadden Ironstone group, and has followed the strike of these beds in a marked degree.

Similar influences are observable in the dissection of the Renfrew Bank. For instance, the long north-west ridge below Scotstoun is formed along an outcrop of the Hosie Sandstone, flanked on each side by a considerable thickness of soft shales. A little further west the dolerite sill known as the " Elderslie Whin " is intruded into these shales, and gives rise to a well-marked ridge. Again, the prominent rock knob on the east side of Renfrew is caused by an outcrop of sandstone surrounded by softer shales.

The low ridge in the old Black Cart valley, at Barnhill, is also readily explained by the presence of a dolerite outcrop, but it is not quite so easy to account for the high ground at the west end of the Bearsden channel, south of Drumry. At this point, however, there is an outcrop of the strong post of sandstone invariably associated with the Upper Garscadden Blackband. The resistance of this bed, which has a considerable thickness of shales both above and below, has in all probability brought about the formation of the high ground south of the hamlet, and also the constriction in the main channel to the north.

The course of these old valleys, at certain points, is of necessity based on somewhat slender evidence. But only in one case, that of the continuation of the old Black Cart valley north of Paisley, is the doubt sufficiently serious to call for remark.

Beyond Paisley, one of two directions must be taken by the channel. It may either run due east to meet the Clyde near Govan, or flow northwards to join the Bearsden valley near Clydebank. But in the former case the direction would not only be at variance with the general drainage lines of the district, but there is the further objection that already, between Paisley and Renfrew, the greatest depth found in the channel (115 ft. below O.D.) exceeds that met with at any part of the old Clyde valley.

The supposition that the stream flowed directly north to join the Bearsden channel, is certainly more probable. That idea involves a breach of the Renfrew Bank, but it is a suggestive fact that at the only point where (as we know from boring evidence) this could take place, the course of the stream would coincide with the strike of the soft shales associated with the Lower Garscadden Blackband Ironstone.

Any explanation of this interesting question, must, however, be regarded as tentative until further evidence has been obtained.

R. G. C.

Among the borings whose results have been utilized in the preparation of the map, particular reference should be made to those put down from time to time along the course of the Clyde by the Clyde Navigation Trust during the operations of deepening the channel, excavating for docks and sinking foundations for bridges. The results of these bores have been placed at the disposal of the Survey by the courtesy of Mr. W. M. Alston, Engineer-in-Chief to the Trust, and it is largely from these that it has been found possible to trace the approximate limits of the pre-glacial valley of the Clyde. On the east side of Renfrew, around Elderslie House, over a hundred bores have been sunk by the Trust, to ascertain the depth and nature of the superficial deposits over the site of a proposed dock. It is obviously impossible to give the whole of the data upon so small a map, but it may be taken that, within this particular area, the contour lines are unusually accurate. Indeed, had it been possible to use a larger scale, a considerable amount of further detail could have been inserted.

The figures on the map, which are calculated to ordnance datum level, show that from Cambuslang to the rock bar at Elderslie the present channel of the Clyde is being eroded, naturally and artificially, through the deep infilling deposits of the early Clyde valley.

Between the Queen's Dock and the mouth of the Kelvin the river is flowing close to the northern bank of the older channel. The steepness of the declivity on that side is shown by the occurrence of rock in the present bed of the Kelvin, just above Partick Central Station, while in the north-western part of the Timber Depôt, close by, the rock is 60 to 70 ft. below the surface. From Carmyle, above Cambuslang Bridge, up to the edge of the Sheet at Bothwell, the Clyde flows almost continuously over a rock floor. At Carmyle the rock bed is approximately 25 ft. above O.D., while the bottom of the pre-glacial valley at Glasgow Bridge lies nearly 100 ft. below. It is therefore obvious that, unless we are prepared to suppose a sudden fall in the river-bed of 120 ft. in a distance of less than four miles, the greater part of the course of the Clyde above Cambuslang must be post-glacial in origin.

The position of the earlier channel in this part of the map can be only approximately determined, the only data available being negative. The evidence obtained in the coal-workings around Cambuslang, and the continuous rock section seen along the Rotten Calder Water, show that it cannot pass through the ground between the Clyde and the foot of Dechmont Hill, while similar evidence round Tollcross and along the North Calder and its tributaries precludes a passage to the north between the mouth of that stream and Coatbridge. A consideration of the available evidence therefore narrows down the possible course of the pre-glacial channel to that shown on the map, the present stream being crossed four times through gaps where no rock is exposed in the river-bed.

The present bed of the Clyde first touches O.D. level at Dalmarnock railway bridge, but there is not sufficient evidence to fix the point where the bottom of the pre-glacial valley passes permanently above sea-level. L. W. H.

(2) SUBMERGENCE OF THE ANCIENT LAND SURFACE.

Evidence will now be brought forward to show that a submergence of this ancient land surface took place shortly before the glacial period, and that the valleys were largely silted up before the advance of the great ice-sheet.

It is well known that, in many parts of the Glasgow district, beds of sand, gravel and mud are intermingled with the boulder-clay. These intercalations, which are often contorted and highly irregular in form, have a more or less definite distribution. They are met with along the site of the pre-glacial valleys of Bearsden and the Clyde; as a general rule boulder-clay only is found in adjacent areas.

The origin of these deposits is somewhat uncertain. They are most conspicuous along the track of the Bearsden valley, where their existence has long been known.[1]

Although equally applicable to the old Clyde valley, the two theories that have been advanced as to the origin of these deposits deal more particularly with those of the Bearsden valley.

The first theory was elaborated by Croll.[2] In agreement with Bennie, he considered that the intercalations were of marine origin. He did not actually find marine fossils in them, but in another buried channel to the east, running into the Forth near Grangemouth, he obtained marine fossils from the red clay which rests on the boulder-clay of that district. This red clay is sometimes 100 ft. in thickness. Reasoning by analogy, he concluded that the deposits filling the Bearsden valley, at any rate down to 100 ft. below sea-level, were also of marine origin. In favour of this view he cites Bennie's record that "cockle-like shells . . . probably *Cyprina islandica*" had been found in a pit east of Blairdardie, at a depth of 54 ft. from the surface, and that at Blairdardie itself, "shells" had been found *under boulder-clay*, when sinking a pit shaft.

The line of reasoning adopted is not very convincing. The Grangemouth red clay is of post-glacial age, and recent mapping has shown it to be almost certain that this is also the case with the clay found in the pit east of Blairdardie. Now the deposits filling the old Bearsden valley must be either pre-glacial or inter-glacial, since the bore records show that beds of "clay and stones" (boulder-clay) are intermingled at all points with the beds of sand, gravel and mud.

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[1] The earliest notice seems to be that by J. Bennie, *Trans. Geol. Soc. Glasg.*, vol. iii., part i., 1868, p. 133, etc.

[2] Climate and Time,' 1875, p. 481, etc.

In the one case where fossils are supposed to have been found under boulder-clay, in the sinking of the Blairdardie pit, there is no evidence that these "shells" were not of fresh-water origin. It cannot be said that Croll was able to bring forward anything like convincing evidence of the existence of marine beds along the site of the old valley, other than those of post-glacial age.

The second theory, less open to objection, is that advanced by Professor James Geikie.[1] He considered that the deposits were accumulated in a lake held up by an ice dam across the mouth of the Clyde valley and draining through the gap in the Renfrewshire Hills near Johnstone.

Both theories, therefore, postulate the existence of a considerable body of water, in which these beds were laid down, and presumably became incorporated with boulder-clay on the subsequent advance of the great ice-sheet. It is natural to suppose that the deposits laid down in so large a sheet of water should now be intercalated with boulder-clay all over the Glasgow district. No such general distribution, however, is found.

The ice-dammed lake[2] required by Professor Geikie may conceivably have existed before the great ice-sheet swept over the site of the Bearsden valley, but it seems improbable that deposits of any considerable amount were accumulated in it.

The history of these sands and gravels is subject to a further interpretation which seems more in harmony with the facts now known. During Tertiary times, the general land surface must have stood at least 300 ft. higher than it does now, and on this land surface the old Bearsden and Clyde valleys were formed. But shortly before glacial times a general submergence took place throughout the British Isles, until the pre-glacial beach level stood only slightly above that of the present day.[3]

While this depression was in progress, river action would produce a gradual silting up of the valleys. Of this depression and infilling of the old valleys there is direct evidence in the case of the Bearsden channel. The abrupt and steep-sided bend at Kessington (*see* map), and also the smaller embayments found elsewhere along the channel, strongly suggest the "incised meanders" of a stream winding over alluvial flats and cutting here and there into the valley sides. The fact that the rock bottom of the old Black Cart and Clyde channels is about 100 ft. above that of the Bearsden channel, also suggests that considerable infilling with alluvial deposits had taken place in the latter while the two former were still flowing over a rock bed. Such a disparity between the levels of the rock bottoms of the main (or Bearsden) and its tributary valleys renders it unlikely that all three streams were flowing over rock at one and the same time.

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[1] 'The Great Ice Age,' 1894, p. 121, etc.

[2] The existence of such a lake was independently suggested by Dugald Bell, 'On the Aspects of Clydesdale during the Glacial Period,' *Trans. Geol. Soc. Glasg.*, vol. iv., part i., 1871, p. 66.

[3] This beach has been observed in Co. Cork, Dublin, the shores of the Bristol and English Channels, Yorkshire and the Isle of Man. A discussion, with references to previous literature, is given by Messrs. Wright and Muff, *Proc. Roy. Dub. Soc.*, 1904, vol. x. (N.S.), part ii., pp. 271-274.

A higher pre-glacial beach level has been recorded by Mr. Wright ('The Geology of Colonsay and Oronsay,' *Mem. Geol. Surv.*, 1911, p. 62), in the Islands of Colonsay and Oronsay, but its relation to the English and Irish one is by no means certain.

On the whole it seems probable that on the advance of the great ice-sheet over the district, the old valleys were already choked with alluvial detritus. The incorporation of these deposits with ground-moraine probably accounts for the heterogeneous mixture of sand, gravel, mud and boulder-clay, now found along the site of these ancient depressions. R. G. C.

(3) DIRECTION OF ICE-MOVEMENTS.

The striæ observed on the Kilpatrick Hills and Campsie Fells indicate an inflow of ice from the north-west; along the southern margin of the Fells the ice-current is deflected towards the E.N.E., parallel to the axis of the Central Valley of Scotland. Certain irregularities of direction noticeable in the Campsie Fells may be ascribed to the influence of the topography in directing the flow of the ice at the maximum stage of glaciation; others should probably be referred to the local glaciation following upon the retreat of the main ice-sheet. E. B. B.

In the lower lying country to the south of the northern ranges, the earliest movement, determined mainly by the form of the ground, was from north to south across the Glasgow area. Striæ indicating this direction of ice-flow are found on the sandstones of Craigmaddie Muir—where they are cut by later groovings pointing a little south of east—in the old Possil quarries at Lambhill, and at Springburn in the northern suburbs of the city.

There is no evidence that this southerly movement extended much to the eastward of Glasgow. From an early period in the glaciation the ice appears to have streamed out to the eastwards through the central valley, as indicated by the invariable easterly (E. 20° N.—E. 25° S.) direction of the striæ and of the long axes of the drums in this part of the area.

At a later period, when the ice-shed of the country lay probably further to the westward, the ice entered the area from the north-west, bearing with it—in even greater numbers than the earlier ice-sheet—the boulders of Highland metamorphic and igneous rocks from the country round the head of Loch Lomond, and of volcanic rocks from the Kilpatrick Hills, that fill the boulder-clay of the Glasgow area, and can be traced far to the east through the central valley. L. W. H.

The presence of boulders, whose source of origin can confidently be placed amongst the rocks of the Southern Uplands, suggests considerable variation in the direction of ice-flow. Thus at Shettleston the "Haggis Rock" was found in the boulder-clay associated with two types of the Garabal Hill granite, grits from the Ben Ledi or Pass of Leny series and Craigmaddie Muir sandstone, as well as numerous porphyritic lavas. In sections near Drumpark the boulder-clay contains, as will be further described, not only pieces of "Haggis Rock," but others of radiolarian chert, like that in the Southern Uplands, and others again of red felsite, identical in character with that of Tinto Hill and the northern side of Carmichael Hill. W. B. W., C. T. C.

The district also includes portions of two boulder trails of special interest, namely those of the Glen Fyne granite and Lennoxtown essexite.

The source of the granite boulders commonly found in the Glasgow district was first determined by Professor Hopkins in 1850,[1] who favoured the view that the blocks had been carried into their present

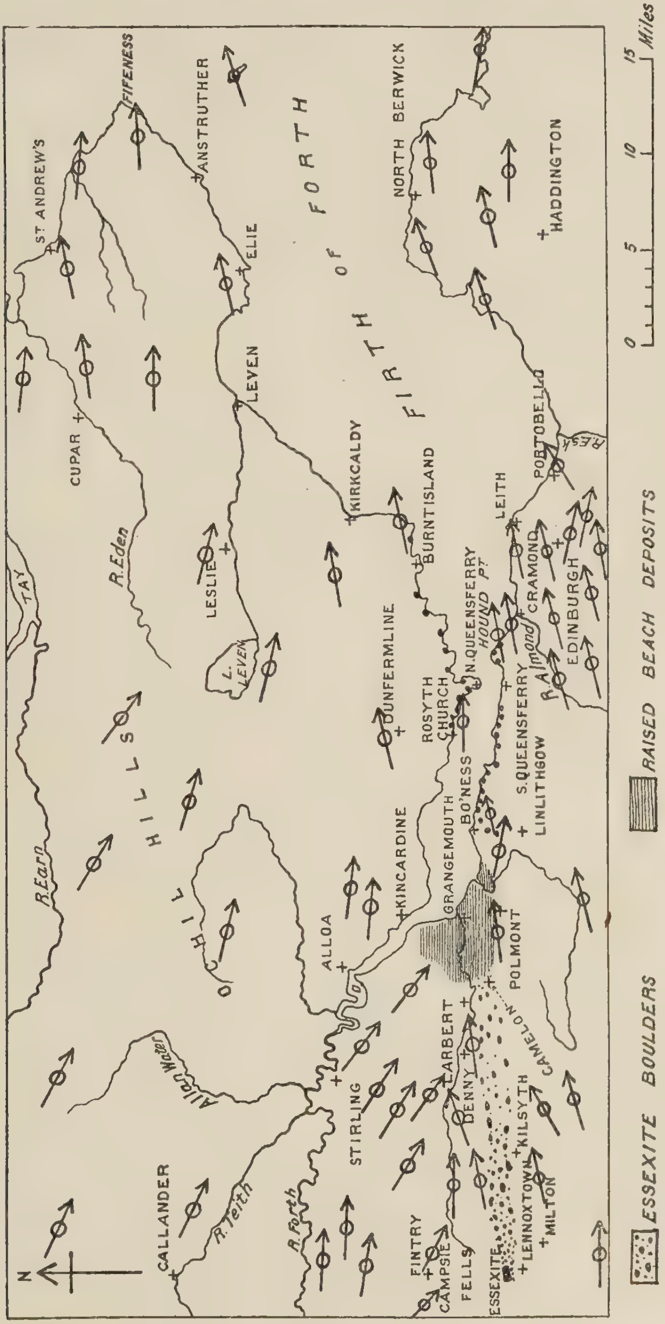

FIG. 23.—Map showing distribution of essexite boulders in the Central Valley, after A. M. Peach.

positions by strong currents of water. In 1892 the same source of origin was independently located by Mr. Dugald Bell,[1] who dismissed floods and icebergs, and restricted himself to land-ice as the only possible agency of transport.

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[1] 'On the Granitic Blocks of the South Highlands of Scotland,' *Quart. Journ. Geol. Soc.*, vol. viii., 1852, p. 20 (with sketch map).

Granite boulders derived from the Glen Fyne mass have been noted in Strathblane, which probably lies near their north-eastern limit of distribution.

The cone of distribution of the Lennoxtown essexite was recently discussed in a valuable paper by the late Mr. A. M. Peach.[2]

His map is here reproduced (Fig. 23) showing the definite set of the current of ice somewhat north of east from Lennoxtown through the Central Valley. It is remarkable that, with a source measuring only 700 by 100 yds., it has been possible to follow the carry of these boulders for thirty-five miles. They are so abundant within a few miles of Lennoxtown that they furnish striking evidence of the importance of glacial erosion in this district. E. B. B.

The Carboniferous plain that stretches eastwards from Glasgow between the valleys of the Kelvin and the Clyde is a region of extensive glacial accumulation, where the rocks are buried beneath an almost universal covering of boulder-clay. The boulder-clay is disposed in long smooth-topped ridges whose forms have been but slightly modified here and there by post-glacial denudation.

The long axes of these ridges or "drumlins" have a well-marked determinate direction, and clearly indicate the general movement of the ice through the Central Valley.

Within the City area north of the Clyde, their trend is almost due east. To the east of Bishopbriggs and Springburn they diverge from this direction and strike E. 10°–20° N. over the Carboniferous plain towards Chryston and Mollinburn; while in the country south of Millerston and Gartloch their direction varies between E. 12° S. and E. 25° S.

In the area lying to the east of Baillieston, and between the North Calder Water and Lochgreen and Lochend Loch, the average trend of the drums is about 23° south of east, and sometimes slightly north of east. Near Lochwood the direction of one of the drums changes somewhat suddenly, the western part striking nearly E.N.E., while the eastern portion trends E.S.E.

The southerly deviation of the ice-movement shown by the drums and glacial striæ is still more marked in the country south of the Clyde. Between Paisley and Pollokshaws their average direction is 25° south of east, and near Thornliebank, south-east and S.S.E., returning somewhat abruptly to a more easterly direction between Rutherglen and Cambuslang.

Many beautifully glaciated surfaces of the Giffnock Sandstone may be seen along the line of outcrop. A movement of the ice varying between east and 24° south of east in the Coatbridge district, is further shown by the striæ seen on a surface of sandstone on the Caledonian railway line between Glasgow and Coatbridge, just within the eastern margin of the map. Other striæ, pointing 4° south of east, occur on the west of the North Calder Water, nearly two-thirds of a mile west of south from the last-named locality.

L. W. H., C. T. C., W. B. W., E. M. A.

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[1] 'On the Origin of Certain Granite Boulders in the Clyde Valley,' *Trans. Geol. Soc. Glasg.*, vol. x., part i., 1895, p. 16 (with sketch map).

[2] 'Boulder Distribution from Lennoxtown, Scotland,' *Geol. Mag.*, 1909, p. 26.

BOULDER-CLAY.

Campsie and Kilpatrick Hills.

The upland districts of the Campsie and Kilpatrick Hills are comparatively driftless, but deep deposits of boulder-clay have been laid down in many of the valley bottoms. The boulder-clay is apt to have an almost flat surface, and where trenched by the streams it is left in the form of terraces. The deposit is generally of a brownish colour, and often somewhat gravelly in texture. In the Upper Old Red Sandstone district to the north the clay is bright red in colour, and it is probable that the red boulder-clay of the Glasgow district, referred to later, owes its colour to Old Red Sandstone detritus carried across the Kilpatrick Hills.

Boulders of metamorphic grits from the Highland Border are abundant everywhere, even in the higher parts of the Campsie Fells.

E. B. B.

Glasgow and the Central Plain.

The boulder-clay of the central plain is commonly deepest on the ridges, where these are drumlin forms of original deposition, and thin, or sometimes absent over small spaces, in the intervening hollows.

A thickness of 40 to 80 ft. of continuous boulder-clay is met with in several bores in different parts of the area, and, in the fine section of a drum exposed at Hamilton Hill Quarry, over 100 ft. of this deposit has been measured.

The ordinary boulder-clay of the district is a tough, grey, entirely unstratified, stony clay, weathering into a lighter and more earthy material towards the surface, and becoming darker and more tenacious in the lower portion.

In several localities an upper boulder-clay of a reddish colour has been observed. On the ridge that extends westwards from Cadder, between the Kelvin valley and the Forth and Clyde Canal, there is evidence that the red boulder-clay that caps the ridge is separated from the grey clay on the south side of the canal by a lenticular bed of sand and gravel. Near the west end of the Wilderness Plantation the sand and gravel thin out, and in a bore on the south side of the wood, 10 ft. of red clay is found resting directly upon 20 ft. of strong blue clay, which is again underlain by 20 ft. of sand and gravel.

The bores put down along the north bank of the Clyde immediately to the west of the Partick Saw Mills also prove the occurrence of a lenticular mass of red stony boulder-clay, with a maximum thickness of 47 ft., between two beds of sand, of which the lower rests again upon hard blue boulder-clay.

Numerous other instances of successive deposits of red, brown and blue boulder-clay, separated by beds of sand and gravel, have been met with in the deep bores sunk through the superficial deposits that fill the pre-glacial valley of the Kelvin. The journals of a large number of these borings were collected by the late Dr. Croll, and are discussed in a valuable paper by the late Mr. Jas. Bennie, who also describes several sections, no longer visible, where the intercalation of beds of sand in the boulder-clay was at the time exposed.[1]

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[1] 'On the Surface Geology of the District around Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. iii., part i., 1868, p. 133.

Grey boulder-clay, succeeded eastwards by apparently overlying red clay, is seen along the North British (now L.N.E.) Railway between East Miller Street and the Netherburn Chemical Works, Parkhead. A number of bores put down in the ground between Provanmill and the Monkland Canal show that the blue boulder-clay, which covers that area to a depth of 15 to 30 ft., is overlain by yellow and brown sandy clay with an average thickness of 6 to 10 ft.

The best boulder-clay section at present exposed within the City boundaries is that already referred to at Hamilton Hill, on the east side of the canal and a short distance south of Firhill basin.

The clay is here quarried to provide puddling material for the canal. The vertical face of the quarry measures 70 to 75 ft. in height, while, the additional depth to which the clay has been excavated in the barge dock below gives a total thickness of at least 100 ft. for the deposit. It is throughout a stiff, grey, stony, unstratified clay, oxidising slightly near the surface, and becoming harder and very dark in colour towards the base. The larger boulders are removed and piled in heaps on the quarry floor, where they can be conveniently studied, and form a most interesting collection.

The majority of the stones are more or less of local origin and derived from the Carboniferous rocks. These include sandstone, blaes and oil shale, limestone, cementstone and clayband ironstone. In addition to these is a large proportion of Carboniferous volcanic rocks, probably from the Kilpatrick Hills.

From the Old Red Sandstone belt further to the west come a few fragments of sandstone and conglomerate, and reddened quartzite pebbles derived from the latter. Numerous boulders of more distant origin, derived from the metamorphic and igneous rocks of the Highland area to the north-west, are also met with. They comprise fragments of pebbly grit, quartzite, vein quartz, mica and chlorite schist, lamprophyre, epidiorite, a porphyritic basic igneous rock, and two varieties of granite, one of which closely resembles the red porphyritic granite of the Garabal Hill complex.

A closely similar assemblage of boulders, including also the red Garabal granite, is found in the clay-pit at the Springburn Brickworks, where a section of 30 to 35 ft. of dark, tough boulder-clay is now visible.

Another good section is afforded by the Robroyston Quarry, where 30 to 40 ft. of very stiff dark grey clay overlies the sandstone and is dug for brick-making. The proportion of locally derived boulders is here larger than at Hamilton Hill, and these consist chiefly of sandstone and calmy limestone. The Carboniferous volcanic rocks and Old Red Sandstone fragments appear to be equally abundant in both places, but there is a marked diminution in the number of Highland erratics. They include, however, most of the types recorded from Hamilton Hill, and, in addition, fragments of grey biotite-gneiss and biotite-hornblende-granite.

At each of these localities the boulders of most distant origin are usually those which are best rounded, smoothed and striated. The largest specimens are almost in every case formed of the pebbly grit of the Highlands, a rock peculiarly tough and resistant to weathering.

At the time of the building of the present University, the boulder-clay was exposed in a quarry opened at the western end of Gilmore Hill, and was bored to a depth of 70 ft. on the summit of that hill. In his paper published in the Transactions of the Geological Society of Glasgow, Mr. John Young describes the deposit, and gives a list of the principal varieties of the included stones, which compare very closely with those given above.[1] L. W. H.

The country west of Glasgow, between Yoker, Douglas Muir, and Bearsden, is covered by a variable thickness of reddish or purple coloured till. The boulders in this clay consist mainly of a variety of Highland rocks (green grits, mica-schists, etc.), together with a few boulders whose origin can be directly traced, such as the Garabal Hill granite. Mingled with these are numerous examples of the lavas of the Kilpatrick Hills, and of the soft quartzose grits overlying that series.

East of Yoker a dark blue boulder-clay suddenly appears, containing boulders that are largely of local origin—clay ironstone, encrinital limestone, dark shales and sandstones of various types being abundant, while Highland boulders are in a minority.

No sections showing the relations of these two boulder-clays were met with at the time of the revision, but a year or two previously such a section was exposed during the excavations for the new Shearer Graving Dock at Blawarthill, three-quarters of a mile south-east of Yoker. According to Mr. Sommerville[2] the red till was the lower. It was 20 ft. thick, and rested on fossiliferous shales. The overlying dark blue clay, with local rocks, was about 25 ft. thick, and was "in places separated from . . . (the red clay) . . . by a layer of fine sand, and in others by a pavement of boulders." It should be pointed out that the inferior position of the red clay, recorded from this section, is quite exceptional. In the numerous bores put down in the Kelvin valley and along the course of the Clyde further to the east, the red clay is invariably found above the dark grey or blue till.

Mr. Sommerville observed in the red clay a boulder containing sphaerosiderite, which he concluded was derived from the Campsie Hills to the north-east. This mineral is, however, common in the Calciferous Sandstones round Duntocher to the north-west, and the boulder more probably came from this direction.

The red till is found north of a line drawn between Maryhill and Yoker, and is usually intercalated with innumerable beds of sand, gravel and "mud." This intermixture chiefly occurs along the site of the well-known pre-glacial channel extending from Kilsyth to Old Kilpatrick, and is probably due to the boulder-clay taking up and incorporating pre-glacial deposits filling up the channel, as the great ice-sheet swept over the district. The till of the Clyde valley east of Glasgow contains similar intercalations of mud and sand. These beds are always lenticular and usually contorted ; shells have not yet been detected in them. Their distribution is quite distinct from that of the post-glacial sands and laminated clays of the 100-foot beach, for they may be found at all levels. Laminated clays are intercalated with boulder-clay at a height of 350 ft. above sea-level in the railway cutting about one mile south-east of Dechmont Hill, south of Cambuslang, and a similar section is exposed in the mineral railway cutting west of Spittal, two and a quarter miles south-east of Cambuslang, at a height of 260 ft.

An excellent section can also be seen in an old sand pit, close to the railway, a little to the south of Bearsden station. Here the red till overlies highly contorted sands, with thin seams of fine clay.

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[1] 'Notes on the Section of Strata in the Gilmorehill Quarry, and Boulder-Clay, on the Site of the New University Buildings, Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. iii., part ii., 1869, p. 298. A collection of these boulders is preserved in the Hunterian Museum, Glasgow.

[2] *Trans. Geol. Soc. Glasg.*, vol. xii., part ii., 1905, p. 265, etc.

In the area south-west of Glasgow the boulder-clay is dark, and the included boulders are mostly of local origin. Intercalations of sand and clay do not seem to occur. R. G. C.

Coatbridge District.

To the east of Drumpark, a little beyond the eastern margin of the map, two divisions of boulder-clay are exposed, the upper one of a red the under one of a dark brown colour. There can be little doubt that both these clays occur also within the area expressed on this map.

In the sections referred to, they both contain many boulders of far-transported rocks, including dolerite, porphyritic basalt or andesite, felsite and other igneous rocks ; some of schist from the Highlands ; some of radiolarian chert of a type found in the Arenig rocks of the Southern Uplands. A specimen of the " Haggis Rock " (conglomerate) of the latter region was also found lying loose near the junction of the two clays, but it was not clear from which it had been derived.

One of the pieces of red felsite from the brown boulder-clay is stated by Dr. B. N. Peach to be identical in character with the felsitic instrusions which occur on Tinto Hill, and near Carmichael Hill, south of Lanark. These intrusions are in the Clyde valley, and more than nineteen miles south-east of the Drumpark section referred to. They have broken through Lower Old Red Sandstone strata, and do not appear to have provided any pebbles to the conglomerates in this formation.

The number of pieces of soft red sandstone of the type common in the Barren Red Measures is much greater in the red clay than the brown, and it is strongly suggested that in this district the colour of the former clay is chiefly due to the incorporation of material from these measures. The contrast in the number of these pieces of red sandstone is the more noteworthy because, in the locality referred to, such sandstone occurs *in situ*, just under the brown clay.

Involved in the drift in the little stream 170 yds. south of Ellismuir No. 3 Pit is a mass of contorted and broken blaes, at least several yards in extent, together with coal, a musselband and hard broken dolerite. This mass of rock overlies a tough brown boulder-clay, and is covered by sand and gravel, which is in turn overlain by more brown boulder-clay. C. T. C.

The remarkable drumlin topography which characterizes the district between Glasgow and Coatbridge is interrupted along a narrow belt of country extending from the neighbourhood of Hallhill in a southerly direction through Springhill and Muirside to Broomhouse. Within this area, which is two miles long and from a quarter to half a mile wide, the east-and-west drumlins are replaced by irregular mounds which have neither the symmetry and elongated form of drumlins nor the steepness and delicate variety of curve which one sees in an area of gravel mounds. These mounds appear to be largely composed of boulder-clay, but there is a fair amount of associated sand and gravel. They occasionally range themselves into a transverse rampart lying obliquely across the obvious direction of ice motion as shown by the drumlins.

The continuation of this belt of mounds to the south of the River Clyde is even more striking than the portion lying to the north of the river. It extends as a lofty rampart in a north-and-south direction from Redlawood to the flanks of Dechmont Hill near Flemington Farm. The drumlin topography being less remarkably developed in this district than it is to the north, the contrast with the surrounding country is in some respects not so pronounced. The ridge has, however, a greater continuity and boldness, and is in every way more striking. Several deep cuttings have been made through it, showing it to be composed for the most part of stiff boulder-clay with a capping of sand and gravel. The junction of the sand and boulder-clay is exceedingly irregular and ill defined, and there is probably a considerable amount of intercalation. Springs issue along the junction, and there has been in consequence much slipping in the older cuttings.

Taken in its whole extent, from the Monkland Canal on the north to Dechmont Hill on the south, this ridge has a well-marked convexity towards the east. It stretches in a crescent across the low ground of the valley of the Clyde, and has not been traced beyond the 250-foot contour either to north or south. As it lies right across the direction of ice motion it must obviously be of the nature of a moraine, but it is most certainly not composed of material borne on the surface of the ice-sheet. On the contrary its materials must have had almost entirely a sub-glacial origin. The *stau-moränen*[1] of the North German Plain seem to be of a similar nature. They are formed of sand, gravel and ground-moraine, which, as pointed out by Schröder,[2] seem to have been thrust forward at the ice-margin during temporary advance. It is probable that the same explanation will apply to this Scottish example. W. B. W., R. G. C.

SANDS, GRAVELS AND BRICK-CLAYS OF THE CENTRAL PLAIN.

A remarkable area of sand and gravel mounds extends from Tollcross through Mount Vernon to Broomhouse. Numerous large pits have been opened along the main road between Tollcross and Mount Vernon with the object of obtaining the sand, which is valuable for moulding and building purposes. Most of these pits show a great extent of horizontal and current-bedded sand, with here and there masses of gravel, while occasionally the gravel forms the greater part of the section. In some of the pits, beneath the finer gravel and sand, a buried ridge or axis of extremely coarse bouldery gravel can be seen to stretch in an east-and-west direction, marking clearly the actual track of the retreating mouth of the sub-glacial river by which the sediments were deposited. The near presence of ice during the deposition of the sands and gravels is further indicated by the occurrence in them of masses and wisps of boulder-clay. These are more especially abundant along a certain horizon in the great Tollcross pit about 25 to 30 ft. from the top of the section.

These gravels and sands appear to have been deposited in a temporary sheet of water impounded by the retreating ice-front. The sands, which lie to a large extent, though not always, above the coarser gravel, settled down in the quieter water at a little distance from the ice-front, while the coarse gravel accumulated at the mouths of the sub-glacial rivers which opened into this temporary lake. W. B. W.

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[1] Wahnschaffe, 'Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes.' Stuttgart, 1901.

[2] H. Schröder, 'Ueber Durchragungszüge und-zonen in der Uckermark und in Ostpreussen,' *Jahrb. d. preuss. geol. Landesanst fur* 1888, Berlin, 1889, pp. 166-211. 'Endmoränen in der nordlichen Uckermark und Vorpommern,' *Zeitschr. d. deutsch geol. Ges.*, 1894, pp. 293-301.

A considerable area of country near Drumpark, with somewhat smooth outlines, is formed of sand and gravel overlying brown boulder-clay. A little further to the south is a smaller area of a similar nature, in which a section, exposed in 1906 on the south side of the brick-works, showed the following succession :—

	Ft.	In.
Stoneless, buff sandy clay, without any clear lamination	3	0
Finely laminated, chocolate-buff or grey clay, with occasional pebbles	0	10
Gravel	0 to 0	2
Boulder-clay.		

The highest clay has been used for brickmaking. As it lies at a level above the 200-foot contour, it cannot belong to the brick-clays of the 100-foot raised beach, nor is it lying in any marked depression of the surface. C. T. C.

Three small patches of brick-clay, two of which have been wrought, occur in the boulder-clay covered ground to the east of Giffnock, where they are represented as alluvium on the map. The clay resembles that of the beach deposits, but lies at an elevation of 150 to 200 ft. above sea-level. It appears to have been laid down in separate lakelets, during or after the retreat of the ice-sheet. E. M. A.

(4) THE RETREAT PHENOMENA OF THE CAMPSIE FELLS.

It has already been pointed out that striæ and erratics alike prove that the Campsie Fells were overwhelmed by Highland ice during the maximum stage of glaciation.

The retreat phenomena are full of interest. In the first place there is a notable absence, within the limits of the Glasgow Sheet, of marginal drainage phenomena. The few examples known may be enumerated at once : two well-defined dry valleys lead westward across the northern spur of Meikle Bin, and may unquestionably be classed as glacial drainage channels ; the col north of Meikle Bin has perhaps been employed in the same manner, and the pass connecting the Carron with Campsie Glen may also have suffered a little erosion from glacially impounded waters. But elsewhere the phenomena of glacial diversion of drainage are so slight that we might, from this circumstance alone, be led to conjecture that the hills retained local glaciers during the retreat of the main ice-sheet.[1] Indeed, the instances cited above may perhaps have originated in connection with the glacier occupying the valley of the Bin Burn.

That local glaciers did indeed exist in certain favoured situations is unquestionable. Boulders of volcanic rock have been carried northwards for a mile or two from the margin of the plateau in the neighbourhood of the Corrie of Balglass, in the very reverse direction to the flow of the main ice-sheet. In the Corrie of Balglass too, and also in a small corrie immediately west of the Newton o' Fintry, there are clearly defined terminal moraines (*see* Fig. 24),[2] marking the last lingering halt of the local ice.

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[1] P. F. Kendall and E. B. Bailey, 'The Glaciation of East Lothian, south of the Garleton Hills,' *Trans. Roy. Soc. Edin.*, vol. xlvi., 1909, p. 20 (issued separately, 1908).

[2] Largely based on the mapping of Dr. Jack.

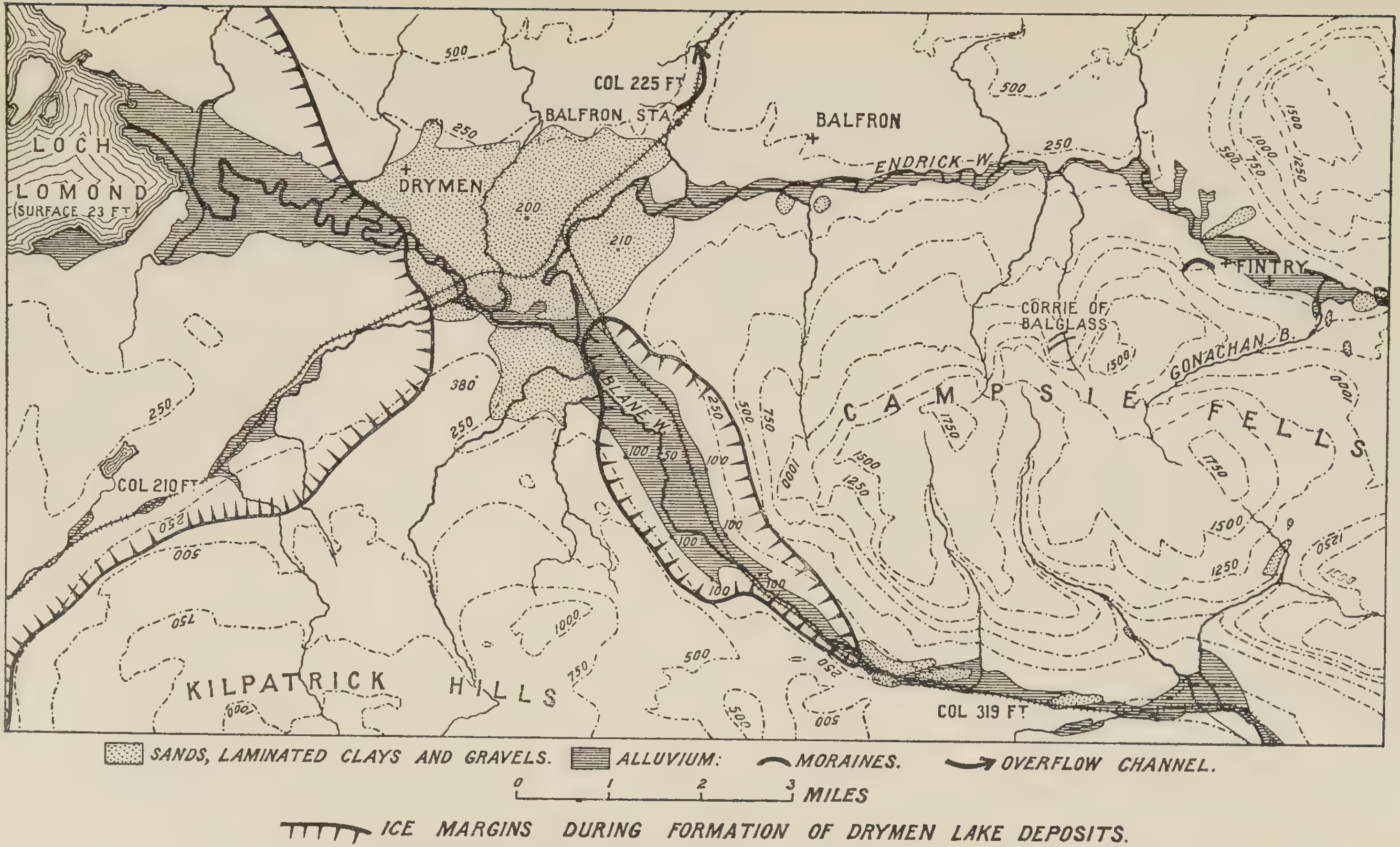

Fig. 24.—Sketch Map illustrating the Phenomena of Local Glaciation in the Campsie Fells.

We may now offer an explanation of two wide stretches of alluvium which fall within the Campsie district.

The Strathblane haugh is three miles long and three-quarters of a mile broad. While its margin agrees very closely with the 100-foot contour, it drains towards Loch Lomond through a gorge cut in fine-bedded sands and laminated clays which, in the neighbourhood, rise to well over 200 ft. R. L. Jack[1] regarded these sands as marine deposits, since they contain rolled marine shells. Professor Jas. Geikie,[2] however, has very truly pointed out that, as the shells which they include are all worn, and as the boulder-clay of the district also contains shells (*cf.* Jack), these deposits do not necessarily indicate a submergence. Professor Geikie accordingly refers them to a glacial lake, since their elevation distinguishes them from any proved marine deposits of the district. In Fig. 24 we reproduce Dr. Jack's mapping of these Drymen deposits. It is clear at a glance that their distribution favours Professor Geikie's interpretation, for it agrees with the hypothesis of a lake held up by Loch Lomond ice and escaping by the pass a little north of Balfron Station. The pass in question is a broad alluvium floored valley. A stream escapes at its western end, but in all probability the direction of the stream in this case has been determined by the building of a "corrom," or delta watershed in the deserted channel after the disappearance of the lake. Either side of the stream, west of the ridge, which apparently served as the lake margin, is a flat which may well be a terrace of erosion cut in the boulder-clay by the waters of the lake.

We now see how the Strathblane alluvium originated. While the Loch Lomond hollow was still occupied by the Loch Lomond glacier, the Strathblane hollow retained a lobe of ice which prevented the Drymen lake from extending into this recess among the hills. On the melting of the ice the deposits of the old lake were left standing up above the hollows on either side.

The Fintry alluvium seems to have originated in much the same manner. Near its head the delta of the Gonachan Burn has been arrested at two distinct levels high above that of the modern delta forming on the valley bottom. It is almost certain that the Fintry valley was at the time occupied by ice, against which the Gonachan Burn laid down its deposits of sand and gravel. The phenomenon is very strikingly developed.

The downstream termination of the Fintry alluvium is determined by a bar of sand reaching across the valley. Probably this deposit formed at the end of the Fintry lobe during a prolonged halt. E. B. B.

(5) DEPOSITS OF THE POST-GLACIAL TERRACES.

Resting upon the boulder-clay, below the 100-foot contour-line, is the well-known series of sands, gravels and laminated clays, whose distribution and faunas were for so long the subject of patient and fruitful investigation by Glasgow geologists.

These deposits give rise to at least two well-marked horizontal terraces. The highest of these runs immediately below the 100-foot contour-line, and has a wide distribution, stretching continuously along the valley of the Clyde above and below Glasgow. The second terrace is much lower, lying about 35 ft. above sea-level, and is only found west of the City.

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[1] 'Notes on a Till or Boulder-Clay with Broken Shells, in the Lower Valley of the River Endrick, near Loch Lomond, and its Relation to certain other Glacial Deposits,' *Trans. Geol. Soc. Glasg.*, vol. v., part i., 1875, p. 20.

[2] 'Great Ice Age,' 1894, p. 281.

The 100-foot Terrace.—There is a well-marked fringe of sand and gravel along the edge of the 100-foot terrace on the west side of Glasgow, and excellent sections across the junction line were recently visible during building excavations east of Halfwayhouse, south-west of the City. Other exposures of a semi-permanent nature may be seen in the mineral railway cuttings under the main road north of Jordanhill House, and north of Knightswood Rows. All these sections show the gravel fringe of the terrace passing insensibly into the boulder-clay, and it is clear that this gravel fringe does not represent fluvial detritus, but was formed by the waves of the old lake washing the boulder-clay along its shores. It is by no means so certain that the laminated clays have originated in such a manner. These clays lie some distance below the gravel fringe, from 50 to 60 ft. above sea-level, and were therefore laid down under 30 or 40 ft. of water. It is quite possible that they may have been partly formed of glacier mud. Good evidence of the presence of glacier ice towards the mouth of the Clyde during the accumulation of these deposits is afforded by the great increase towards the west in the proportion of foreign boulders found in them.[1] Moreover, the fauna of the Loch Lomond shelly boulder-clay[2] is very similar to that of the 100-foot clays near Glasgow. If the latter were contemporaneous with the clay beds from which the Loch Lomond shells came, it is clear that glacier ice was moving out of Loch Lomond during, or shortly after, the deposition of the Glasgow clays. There is still another point in favour of the glacial origin of part of these clays. At Drumchapel there is a sudden drop in the terrace line, which is no longer observable to the west. For some distance south of the point where this interruption occurs there is a line of mounds which may perhaps represent the detritus accumulated along an ice-front.[3]

Although sections of the shelly clays are frequently exposed in temporary excavations, more permanent exposures are few in number. Good sections can be seen in the Drumchapel brickfield, and a particularly good section, rich in shells, is visible at the Seedhill clay-pit, on the east side of Paisley, beyond the limits of the map. *Cyprina islandica* is extremely common here, but many other shells can be found. The boulders scattered through the clay in this pit usually have their upper surfaces covered with *Balani.*

Messrs. Crosskey and Robertson give long lists of fossils from the clays west of Glasgow.[4] While the fauna is decidedly arctic, instances of its gradual replacement by a more temperate one do not seem to be recorded. It is interesting, however, to note the gradual rise of the land indicated by the discovery made by these observers that the Jordanhill shell-beds were covered by a deposit of littoral shells.

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[1] For instance, the clays in the Polmadie brickfields, east of Glasgow, are practically without boulders, which are, on the other hand, plentiful in the Seedhill clay-pit at Paisley.

[2] R. L. Jack, 'Notes on a Till . . . with Broken Shells . . . near Loch Lomond,' *Trans. Geol. Soc. Glasg.*, vol. v., part i., 1875, p. 9.

[3] On the south side of the Clyde, however, the 100-foot beach persists normally at least as far west as Bishopton; *see* Summary of Progress for 1914, *Mem. Geol. Surv.*, 1915, p. 52.

[4] *See* especially their account of the Jordanhill clays, 'Post-Tertiary Fossiliferous beds of Scotland,' *Trans. Geol. Soc. Glasg.*, vol. iv., 1874, p. 241.

Further east the marine fauna gradually dies out. Within the City, at Muirhouses, Eglinton Street, Mr. Bennie could only find "two species of foraminifera . . . five species of entomostraca, a young specimen of *Cyprina islandica*, and occasional groups of *Mytilus edulis*."[1] Still further east, in the Polmadie brick-fields, he only found one species of foraminifera. "Shells" are said to have been met with, 25 ft. from the surface, in the Caledonian clay-pit at Polmadie, but no organisms were discovered in these clays during the recent revision of the area. It is quite possible that the micro-organisms above noted may have been directly derived from the local boulder-clay, which has been shown to contain them,[2] but at any rate it seems clear that the clays east of the City were laid down under estuarine, and further to the east, probably under fresh-water, conditions.

R. G. C.

A large area within the City on the north side of the Clyde is covered by the brick-clays of the post-glacial terraces. Most of this ground is now built over, and the brickfields of Kelvinside and the western suburbs are abandoned, but the extent of the brick-clay in the heart of the City has been traced in the excavations along the line of the subway, the different City railways, and elsewhere.

The upper limit of the terrace deposits closely follows the 100-foot contour-line; the lower merges into the alluvium of the Clyde at different levels between 50 and 30 ft.

The brickworks of the Parkhead and Dalbeth district in the eastern suburbs provide good sections of the brick-clay.

In the Belvidere Pit, 42 ft. of laminated brown clay, with occasional calcareous concretions, rests upon soft mud, and is covered with 3 ft. of sand thinning out to the south. The sand is current-bedded and contains rolled fragment of coal, carbonized wood, and quartz pebbles, and is probably an alluvial deposit of the Clyde. The surface of the clay is here about 56 ft. above sea-level. At Polmadie, on the south side of the river, the Caledonian Brick Works pit shows a covering of 3–4 ft. of yellow and grey-blue sand above 40 ft. of blue brick-clay, with "running mud" beneath. Unbroken "shells" are said to have been obtained from thin sandy seams in this pit, 25 ft. from the surface. In Stevenson's pit, a short distance to the east, the blue clay is 60 ft. thick, with a cover of 3 ft. of sand. These pits are about 35 ft. above sea-level.

L. W. H.

Beyond the sheet of alluvium which borders the Clyde on the south within the City area, lies a tract of ground covered with the brick-clays of the 100-foot beach. Through this deposit rise numerous low boulder-clay drumlins, sometimes elongated in an E.S.E. direction, and sometimes rounded or irregular in outline; the latter probably contain a core of rock. Sandy deposits occur in places along with the brick-clay, and have no doubt been deposited in the same manner. The brick-clay extends more or less up to the 100-foot contour-line, and covers all the less elevated ground to the north of the White Cart.

E. M. A.

(6) *Later Terraces.*—The evidence for the geological history of the

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[1] 'Further Observations on the Surface Geology of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, p. 262.

[2] Neilson, 'On the Occurrence of Marine Organisms in the Boulder-Clay of the Glasgow District,' *Trans. Geol. Soc. Glasg.*, vol. x., part ii., 1896, pp. 273-279. Wright, 'Boulder Clay, a Marine Deposit,' *ibid.*, pp. 263-272.

district after the time of the 100-foot beach (outlined above) has of necessity been drawn from extraneous sources, since such evidence as may have existed has been obscured by the deposition of the Clyde alluvium.

On the north side of the river, between Whiteinch and Drumchapel, there is a well-marked terrace about 35 ft. above sea-level, which is also seen south of the river near Craigton House. But in the absence of sections it is impossible to say whether this represents the 50-foot beach, or is a high-level alluvium of the Clyde. All traces of the 25-foot beach seem to have been covered up by the river deposits. In the introductory paragraphs (p. 215), it is stated that previous to the formation of the 25-foot beach a considerable elevation and subsequent depression of the land surface took place. The evidence of these oscillations lies in the discovery, in various parts of Great Britain and Ireland, of a forest bed covered by the 25-foot beach deposits.[1]

(7) With regard to the age of the 25-foot beach, the consensus of opinion seems to be that the elevation of the beach was completed in Neolithic times.[2] After the formation of the 25-foot beach a slight depression seems to have set in, judging by evidence obtained near the mouth of the Clyde.[3]

FRESH-WATER ALLUVIUM.

River Terraces.—The top of the highest terrace on the North Calder Water is estimated to lie about 45 ft. above the ordinary water-level, while its base is close to the 100-foot contour. It is best seen on the south side of the stream, opposite Bredisholm House. Half a mile further to the east, and on the same side of the stream, the top of the terrace is 28 ft. above the water-level, but at much the same height above ordnance datum as that already referred to. Possibly both these terraces were synchronous with the 100-foot raised beach.

C. T. C.

A high-level terrace of sand and gravel, at an average elevation of about 170 ft. above sea-level, can be traced more or less continuously along both sides of the Kelvin valley to the west of Kirkintilloch. Between that place and Cadder the terrace forms a wide, well-marked feature, and is largely composed of finely laminated clayey sand with intercalated pebbly beds. Elsewhere the terrace feature is often interrupted by denudation, and eastward from Kirkintilloch becomes difficult to trace.

There is good reason to believe that this terrace may represent a margin of a glacial lake which at one time occupied a part of the Kelvin valley. Mr. Carruthers has advanced the view[4] that the sands and gravels that fill up the old channel of the Kelvin are mainly of preglacial origin. It is, however, probable that the fine-grained alluvial surface deposits above referred to, were laid down in a lake, which occurred as a temporary feature during a comparatively late phase of the glacial period.

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[1] *See* for example, Jamieson, *Q.J.G.S.*, vol. xxi., 1865, p. 183, etc.

[2] *See* especially Coffee and Praeger, on 'The Larne Raised Beach,' *Proc. Roy. Irish Acad.*, vol. xxv., 1904, Section C., No. 6, pp. 143-200.

[3] *See* the interesting paper by Mr. James Neilson, 'The Geology of the Clyde Crannogs,' *Trans. Geol. Soc. Glasg.*, vol. xii., part iii., 1906, pp. 273-289.

[4] *Ante*, p. 219.

The Kelvin, in its course across the northern part of the map, has cut a wide channel through the earlier glacial deposits of the Kelvin valley. Between Kilsyth and Kirkintilloch the average breadth of the flood-plain reaches nearly three-quarters of a mile, and other extensive stretches of alluvium are found in the Balmore Haughs and between Summerston and Killermont.

Isolated patches of sand and gravel at a higher elevation rise above the alluvial plain at Inchbelly, Inchbreck and Netherinch, and it has been pointed out by [Dr.] John Young and by the writer of the Statistical Account of Kirkintilloch Parish, that these "inches" preserve the memorial of the time, within the historic period, when these elevated areas rose as islands above the flooded low-lands.[1]

The Glazert, Luggie Water, White Cart, and other smaller streams in the area are bordered by strips of alluvium of varying breadth.

PEAT.

The numerous irregularly shaped patches of alluvium scattered over the central portion of the map usually occupy hollows between the boulder-clay drums, and indicate the site of wholly or partially drained glacial lochans. Most of these alluvial tracts are more or less peat-covered, but have largely been reclaimed.

Large peat-covered areas of this nature occur to the south of Steps and Garnkirk; at Cardowan Moss, where the deposit is 7 to 14 ft. in depth, the peat is being dug and dried for moss litter and packing purposes. L. W. H.

Extensive peat-mosses almost connect Bishop Loch with Woodend and Lochend lochs. On the west side of the last-mentioned piece of water the peat has been proved by three borings to be as much as 23 ft. in depth. It seems probable that the surface underlying the peat is in many parts below the level of both these lochs. The depth of the peat between Woodend and Bishop lochs, at a point 240 yds. west of the north-west end of the former, is found to be 15 ft.

In most parts of these mosses large roots of Scots fir (*Pinus sylvestris*) are very abundant near the top, but between Lochgreen and Heatheryknowe House oak is more commonly found. C. T. C.

Peat is very widely developed on the smooth summits of the Campsie Fells. E. B. B.

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[1] Young, 'On the Geology of the Campsie District,' *Trans. Geol. Soc. Glasg.*, vol. i., part i., 1860, p. 13. 'New Statistical Account of Scotland,' vol. viii., 1845, Dumbarton, p. 173.

CHAPTER XII.

PHYSICAL FEATURES.

THE area represented in the Glasgow District Map lies at the western extremity of the great Midland Valley of Scotland, which has been carved by denudation out of the softer Carboniferous and Old Red Sandstone strata, let down between the bounding faults that on the north side form the southern limit of the metamorphic rocks of the Highlands, and on the south the edge of the Silurian plateau of the Southern Uplands.

The region presents two strongly contrasted types of surface relief. In the north, and, to a lesser degree, along the southern margin of the map, we find a series of bold features produced by the denudation of the hard rocks of the volcanic plateaux.

A softer topography characterizes the central plain, where the features are almost entirely due to glacial accumulations, and the few rock forms that emerge from the well-nigh universal covering of drift are themselves moulded by glacial action.

RIVER SYSTEMS.

The whole of the country south of the watershed of the Campsie Fells falls within the drainage basin of the Clyde. The head waters of the Carron River, which flows eastwards to the Firth of Forth, drain a small tract to the south of Fintry. The other streams of the area are the Endrick and its tributary the Blane Water, which flow through Loch Lomond to the Clyde; the Kelvin, draining the southern slopes of the Campsie and Kilsyth Hills; the North and South Calder Waters joining the right bank of the Clyde above Glasgow; and on the south side of that river, the Rotten Calder Water and the White Cart.

The Clyde.—A study of the physiography of a larger region outside the limits of the map, suggests the probability that the present river and its estuary are due to the combination of two rivers, opposite in course, and of different ages.

The estuary below Dumbarton seems to represent the lower course of an earlier consequent river, which flowed south-eastwards through the transverse valley now partially submerged and occupied by the waters of the Gareloch and Loch Goil.[1]

The existing Clyde, upwards from Dumbarton, is a later obsequent stream which has cut back in an opposite direction, and owes much of its present volume to its obvious capture of the torrent streams above Thankerton from the drainage basin of the Tweed. L. W. H.

That the waters of a part of the Forth basin have also been transferred to that of the Clyde is apparent too from a consideration of the present course of the River Endrick.

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[1] H. M Cadell, 'The Dumbartonshire Highlands,' *Scottish Geogr. Mag.*, vol. ii., 1886, pp. 337-347. *See* also H. J. Mackinder, 'Britain and the British Seas,' 1902, ch. ix, p. 131.

Beyond question the upper portions of this river belonged originally to the Carron,[1] which enters the estuary of the Forth at Grangemouth. To-day the Endrick finds its way westward, having been intercepted by a tributary of the Loch Lomond basin, which in turn unites with the waters of the Clyde at Dumbarton. E. B. B.

Topography of Glasgow and the Central Plain.

The southern portion of Glasgow is, for the most part, situated on the flat plain of fresh-water alluvium and raised-beach deposits which extends with varying breadth on either side of the Clyde. On the north side of the river the ground rises somewhat steeply from the margin of the alluvial plain, and the central part of the City, with its northern and western suburbs, covers a series of roughly parallel, smooth, rounded ridges, trending a little to the north of east. The contours and disposition of these parallel features have been largely determined by glacial action, modified to some degree by differential erosion of harder and softer strata, and their general trend corresponds to the direction of movement of the ice-sheet through the Central Valley.

Most of these ridges contain a core of rock, more or less covered with drift ; in some the rock is at or close to the surface, while others, like Hamilton Hill, are composed throughout of boulder-clay.

The most conspicuous feature within the City, the Necropolis Hill, is due to the outcrop of a teschenite-dolerite sill, and offers a good example of "crag-and-tail." Rising steeply with a bold front to the west above the hollow that separates the Cathedral from the Necropolis, it forms the bare glaciated summit of Golf Hill and Dennistoun, and falling gently to the east in the direction of ice-movement, passes gradually beneath the smooth drift-covered slopes of Haghill and the Alexandra Park.

A further outcrop of this sill to the east of the Park gives rise to a series of low rocky features about Gartcraig, Riddrie and Milncroft ; beyond that point they are almost completely masked with drift.

A remarkable feature in the topography of the district south of the Campsie Hills is the small influence of either pre-glacial or post-glacial denudation on the present surface relief. The great pre-glacial valleys of the Clyde and of the Kelvin are almost completely buried in drift, while post-glacial surface erosion is only represented by a few stream gorges and minor dry valleys.

On the other hand the evidence of glacial action is everywhere apparent. A great part of the district is thickly swathed in boulder-clay, disposed in long ridges and producing the characteristic "drumlin" topography of the Central Valley.

The few exposures of the harder sandstones and igneous rocks that appear above the almost universal drift-covering have all been more or less shaped and modified by ice action, and on every surface calculated to retain the ice-markings, will be found indications of the direction of movement of the superincumbent ice.

One of the few pre-glacial features independent of the direction of glaciation is found within the City boundaries. It appears to be due to the insistence of a particular band of hard rock, and follows the outcrop of the coarse pebbly sandstone that immediately overlies the Index Limestone. It gives rise to the line of bare rock ridges which runs east-north-east from North Woodside through Rockvilla to the Cowlairs Railway Works, and thence, turning to the north, forms the high ground of Springburn and Bishopbriggs.

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[1] *See* pp. 239, 240

The deep gorge cut by the Kelvin in the Carboniferous Limestone strata between Garscube House and Kelvingrove affords the best example of post-glacial denudation within the Glasgow district. The stream flows over rock at Yorkhill, within a third of a mile of its junction with the Clyde, and its bed at this point is at least 60 ft. above the bottom of the pre-glacial channel of the main river. The gorge of the Clyde below Bothwell Castle, the course of the Rotten Calder below Spittal, and that of the North Calder Water from its junction with the Clyde to the edge of the map, may all be regarded as features due to post-glacial erosion, while to these may be added some of the gullies and ravines cut by the streams flowing off the Campsie Hills.

The dominant surface features of the country east of Glasgow, between the Kelvin and the Clyde, are the smooth, gently rounded ridges of boulder-clay already referred to. The long axes of these drums have a general west-and-east direction, diverging slightly to the north of east towards Lenzie and Chryston, and to the south of east as they approach Coatbridge. Between the ridges lie winding flats of peaty or alluvial soil that indicate the position of former drift-dammed lochans. Many of the larger hollows are still filled with water, such as Johnston and Bishop Lochs. The imagination pictures the surface of this country at the close of the glacial period as very similar to that of the Siberian tundras—an alternation of marshy hollows and drier stony ridges, extending in dreary monotony towards the horizon on every side.

It is somewhat remarkable that no single one of the powerful master faults that cross the Carboniferous area south of the Campsie Hills gives rise directly to any visible surface features, although the lateral shift of the outcrop of the dolerite sills has in some cases displaced and interrupted the continuity of the features due to the outcrop of the harder igneous rock.

The east-and-west dolerite dykes, which are in some parts of their course coincident with the line of a fault, often rise in abrupt wall-like features that can be followed for a considerable distance, as for instance between Myremailing and Claddens; to the east of Lenzie; and between Muckcroft and Mollinburn. L. W. H.

Area South of the Clyde.—On the south side of the Clyde, the extensive alluvial flats bordering the river are succeeded further to the south by a broad belt of country marked by smooth-featured mounds with intervening stretches of more or less flat ground—a combination of forms due to the penetration of the 100-foot beach into a drumlin-covered area.

Rock features are rare and quite unimportant. South of a line drawn between Shawlands and Nitshill, the belt gives place to a drift-covered region, in which rock-features, though still playing but a small part in the surface-relief, become more and more prominent as the volcanic plateaux of the Renfrewshire Hills are approached. The most noticeable of these features is the low escarpment of the Barrhead Grit around the western and southern sides of the Arden basin.

Area North of the Clyde and West of Glasgow.—On the further side of the river, it is only within the western confines of the City that the flat surfaces of the post-glacial terraces are broken by drumlin mounds. Further to the north, in the direction of Bearsden and Milngavie, the surface topography has much in common with that south of the Clyde, the foot of the volcanic plateau being separated from the alluvial flats by a similar broad tract of country irregularly covered with glacial deposits. As before, the rock-features increase in importance towards the volcanic hills, but do not become predominant until we reach the moorlands beyond Milngavie, with their well-marked escarpments of pebbly sandstone. R. G. C.

The Campsie and Kilpatrick Hills.

The Campsie Fells constitute a high undulating plateau, rising in many places more than 1500 ft. above sea-level, and attaining 1894 ft. in Earl's Seat, and 1870 ft. in Meikle Bin. This elevated plateau consists entirely of volcanic rocks, for the most part lavas lying fairly flat. In its interior it is traversed by many valleys, but its scenery is remarkably featureless save for the terracing of the steeper slopes.

The low ground to the north and west of the Fells has resulted from the removal by erosion of the volcanic pile, and the comparatively rapid wasting of the underlying sedimentary rocks; its smooth slopes are here and there interrupted by isolated hills, marking the presence of old volcanic vents as described in Chapter VIII. The low ground to the south is also determined by soft sedimentary rocks, in this case thrown down by the great Campsie fault.

The western face of the Fells is a normal escarpment of lavas crowning a steep slope of Ballagan sediments. The northern face is also an escarpment, modified, however, by several volcanic vents. The southern face is for much of its course a steep fault scarp, revealed and cut back by erosion. E. B. B.

The Kilpatrick Hills continue the upland tract to the south-west on the other side of the Blane Valley. Within the limits of the map they scarcely reach the 1000-foot contour, and their highest elevation to the west is only 1313 ft. They are thus markedly lower than the Campsie Fells.

The lavas which build up the Kilpatrick Hills are a portion of the same great group that constitutes the Campsie Fells. They are arranged, however, with a well-marked inclination towards the south-east, and the plateau character of the latter range is accordingly replaced by successive dip slopes and escarpments. Seen from any point of vantage, the unending series of scarps of the Kilpatrick Hills forms a most striking spectacle. The terraced hillsides, the little lochs reposing in front of the scarps and the rich vegetation which covers part of the ground, combine to form a picture of quiet and restful beauty. G. W. G.

These preliminary remarks show how close a connection exists between the scenery of the Campsie-Kilpatrick district and its geological structure.

We may now turn to the consideration of the drainage system of this interesting region. The lower ground, and even the Kilpatrick Hills, present very complex material for study, since secondary adjustment has proceeded so far that little remains of the original system; but the Campsie Fells, including in this term the Kilsyth and Fintry Hills, afford a charmingly instructive example of river development.

Almost every stream within the limits of the Fells was in the beginning tributary to the River Carron. At that time the Campsie Fells had no separate topographical existence; they were portion of an extensive upland tract, probably continuous with the Highlands to the north;[1] they had yet to be delimited by the processes of erosion.

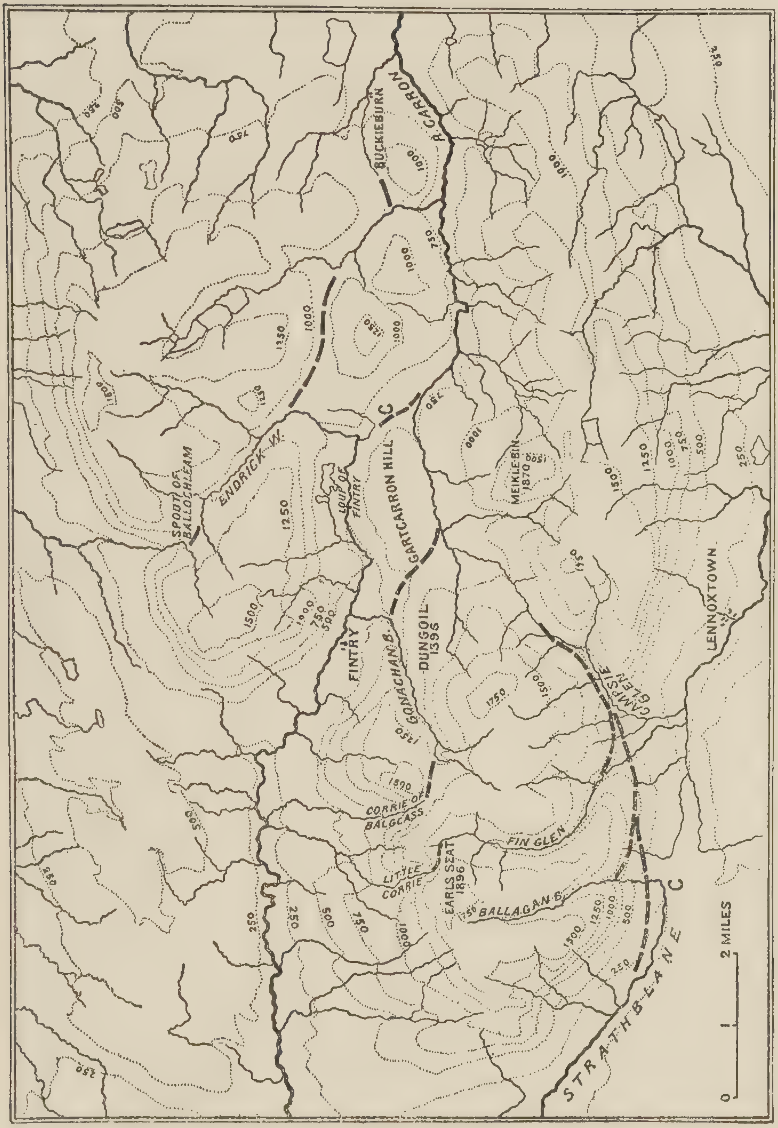

FIG. 25.—Drainage System of the Campsie Fells. C = Corrom. Heights given in feet.

As the attack proceeded and the Campsie Fells were isolated, the original drainage survived only in the hill fastnesses; here it is found, greatly modified it is true—wherever intercourse with the surrounding lowlands has been possible—but still clearly recognizable.

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[1] H. J. Mackinder, 'Britain and the British Seas,' 1902, pp. 126-133.

We shall now illustrate these remarks by reference to some special features of the drainage system.

The valley of the Upper Endrick has obviously been curtailed by the retreat of the northern escarpment of the Fells, and the drainage of its upper portions has been diverted by an obsequent stream giving rise to the Spout of Ballochleam.[1]

The result has been the specially rapid retreat of the escarpment along the course of the obsequent stream, and the formation of what may fitly be termed an obsequent corrie.

The down-stream continuation of the valley of the Upper Endrick Water can readily be followed to Buckieburn, although its course is intercepted at two points and the waters carried by shorter routes into the Fintry valley—the great through valley of the Fells.

On the other side of the Fintry valley we may note two additional instances of the curtailment of the drainage system through the retreat of the northern front of the hill country. The head of the Gonachan Burn is connected by a wind gap with the obsequent Corrie of Balglass, and the head of the Fin Glen is in like manner connected with the Little Corrie.

With these three instances before us there can be little doubt as to the interpretation of the Fintry valley itself. It is clearly the valley of the original Carron, truncated by the retreat of the northern front of the hills and modified by the obsequent drainage.

As is not uncommon in the case of beheaded river systems, the divide between the consequent and obsequent drainage of the Fintry valley is a " corrom " or delta watershed.[2] The " corrom " here has been built by a small stream acting in conjunction with the Upper Carron, which is thus preparing, as it were, to hand itself over to the obsequent drainage. The transfer will be made permanent in the future when the waterfall of the Loup of Fintry works its way back to the site of the divide.

The next link in the evidence is furnished by the well-marked hollow by which the road crosses the hills from Fintry to Lennoxtown. The gap between Dungoil and Gartcarron Hill probably represents the original course of the Gonachan Burn on its way to join the Carron; this burn now finds its way directly into the Fintry valley. The gap connecting the Carron with Campsie Glen is much more important; we can here recognize a through valley in which the Campsie Glen stream is almost certainly obsequent, trapped by the rapid erosion of the downthrown sedimentary rocks of the Lennoxtown district. According to this interpretation, the Campsie Glen valley was the original continuation of Strathblane, and conducted the water of Ballagan Burn and the Fin Glen into the Carron.

But even the modified Strathblane, continuing past Lennoxtown, was unable to maintain itself against encroachment from the north. Like the Fintry valley it has been beheaded and has received a corrom as its watershed, in this case built up by the waters of the Ballagan Burn.

All these readjustments were essentially complete in pre-glacial times, save that perhaps the modern corroms may be somewhat differently situated from their pre-glacial forerunners. Certainly the valleys to which we have referred are all pre-glacial, with, as a rule, deep accumulations of boulder-clay in their bottoms, and naked rock sides above. Where the boulder-clay has been in part removed by streams since the ice age, its remnants form terraces on either side of the valley, a feature clearly illustrated along the hollow connecting Campsie Glen with the Carron, and better still, perhaps, in the valley of the Gonachan Burn.

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[1] The features here described recall Prof. W. M. Davis' paper on 'The Drainage of Cuestas,' *Proc. Geol. Assoc.*, vol. xvi., 1904.

[2] P. F. Kendall and E. B. Bailey, 'The Glaciation of East Lothian, South of the Garleton Hills,' *Trans. Roy. Soc. Edin.*, vol. xlvi., 1909, p. 8 (issued separately, 1908).

Post-glacial erosion has not been great. Several of the streams have gouged deeply into the soft Cementstone Group, as at Ballagan and the Little Corrie. The erosion of the more resistant lavas in the Campsie Glen is also in part post-glacial, instigated perhaps by the widening of the Blane valley by direct glacial erosion; there is no doubt that the ice-sheet must have ground down and plucked off a considerable amount of solid rock, as well as cleared away an immense litter of slipped material. Since the retreat of the ice, landslips have been numerous all along the steep borders of the Fells. They often occur at the junction of the lavas with the underlying sediments, leaving a naked scar of bedded lava above and an immense trail of debris below; one of the most important is seen at the eastern entrance to the Corrie of Balglass; others, affecting a portion only of the lava group, border the road leading up the hill from Lennoxtown.

The formation of the haugh lands of Strathblane and Fintry has been already discussed (p. 230), and it is sufficient to state here that they probably represent the "casts," as it were, of lobes of ice, left on the retreat of the great ice-sheet. E. B. B.

The history of Glasgow affords an interesting example of the influence of geographical and geological conditions on the rise and progress of a great industrial centre.

The development of the early settlement on the banks of the Clyde into an important centre of population was primarily determined by its geographical position at the meeting of the ways. Situated at the mouth of the Great Midland Valley—the natural channel of communication from east to west—its advantageous position at the outlet of the main arteries of traffic, by road, canal and railway, from the eastern capital and the ports of the Firth of Forth, is at once apparent. Here, too, converge the two great natural lines of approach from the south; the one passing south-eastwards up the valley of the Clyde and down Annandale to Carlisle, the other coming from Dumfries and the low ground of Ayrshire through the Dalry and Johnstone Gap to Paisley.

The importance of Glasgow as a seaport, and her ready access to the Western Seas, seem at first sight due entirely to her geographical position at the head of the noble estuary of the Clyde. Yet the early settlers can have had no prophetic vision of ocean-going vessels lying at the Broomielaw, where, in the latter half of the eighteenth century, the river could be forded at low tides, while vessels of any burthen could not pass beyond Dumbuck, twelve miles below Glasgow, where was a ford with only 2 ft. of depth at low water.

Since the year 1755 the bed of the river between Glasgow Bridge and Dumbuck Ford has been deepened 20 to 29 ft., with the general result that it is practically level between Glasgow and Port Glasgow. The average depth of the Lower Harbour at low water is 18 to 20 ft., of the Upper Harbour, above Glasgow Bridge, 10 ft.; while the greatest draught of vessel able to ascend the river has increased from 13½ ft. in 1821 to 26½ ft. in 1900.[1]

Had the river flowed in its lower reaches, as it does above Cambuslang Bridge, over a shallow rocky bed, the difficulties of carrying a deep water channel up to the heart of the City would have been almost insuperable. The fortunate coincidence, however, of the course of the Clyde, through and below Glasgow, with a pre-glacial channel filled with clay, sand and gravel, has facilitated the excavation of large docks, enabled a passage to be dredged deep enough to admit vessels of the largest size, and thus rendered possible the rise and progress both of the commercial prosperity of Glasgow and of the great shipbuilding industry of the West of Scotland.

But apart from the advantages of situation for approach by land or sea, Glasgow owes most of her prosperity to the presence and accessibility of valuable coal, iron and fireclay-bearing strata of Carboniferous age. These rocks, by an accident of geological structure, have been let down between the faults which bound the Midland Valley on either side, and thus preserved from the denudation which has completely removed them from other parts of the country. Furthermore, the disposition of the beds in gentle undulating folds, and the numerous cross faults by which the strata are repeatedly upthrown in the same direction, cause the most valuable coal seams to be brought within a workable distance from the surface over a wide area.

Lastly, the occurrence, in the near vicinity, of beds of freestone, and of numerous intrusions of hard igneous rock, has afforded a ready supply of building stone and excellent material for street paving and road-metal, contributions of great value to the amenity of a great city.

L. W. H.

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[1] The above facts and figures are taken from a paper, 'The River Clyde and Harbour of Glasgow,' read before the International Engineering Congress, Glasgow, 1901, by Mr. W. M. Alston, Engineer-in-Chief to the Clyde Navigation Trustees.

CHAPTER XIII.[1]

LIMESTONES: ROAD METAL: BUILDING STONES: WATER SUPPLY.

1. Limestones and Cements.

Very little limestone is now raised within the Glasgow district. The plaster works and other industries within the city in which lime is employed, draw their supplies from outside sources, mainly from the chalk of the north of Ireland.

The limestones which have been chiefly worked within the Glasgow district are the Hurlet, the Calderwood Cement of East Kilbride, the Lyoncross, the Orchard and the Calmy or Arden. For information regarding the thickness and character of these in different localities reference should be made to the stratigraphical description given in Chapter IV. L. W. H.

The following analysis[2] of the Hurlet Limestone from the Garscadden Pits may be quoted :—

Limestone.	
CaO	50·99
MgO	1·10
Fe_2O_3	0·72
H_2CO_3	41·46
H_3PO_4	0·27
S	1·28
FeS	1·12
Al_2O_3	1·04
SiO_2	1·60
Organic matter	0·16
Moisture	0·26

Lime.	
CaO	85·96
MgO	1·85
Fe_2O_3	0·05
H_3PO_4	0·45
H_2SO_4	3·24
Al_2O_3	1·75
SiO_2	2·70

Yield of burnt lime, 59·32 per cent.
Sp. Gr. 2·727. Weight of one cubic foot, 170 lbs.

The Index Limestone seems to be of little economic value in this area. A pit was sunk to it to the west of Wardhill, near Nitshill, and it was also worked to a small extent near the new railway at Auchinback. The limestone, however, is too ferruginous for building purposes, and hardly of good enough quality for a cement, besides being

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[1] In the first edition of this memoir a special chapter was devoted to the economic geology of the Glasgow district. Those portions of it dealing with the coals, ironstones and fireclays have been substantially embodied in the stratigraphical account of the Carboniferous rocks given in Chapters III. to VI. of the present edition. For further information the reader is referred to 'Economic Geology of the Central Coalfield,' Area V. (*Mem. Geol. Surv.*, 1916), Area IV. (1920), and Area VII. (1920) which give a detailed description of the economic geology of the greater part of the area included within the Glasgow Sheet. A second edition of 'Area V.' is in preparation and will shortly be issued.

[2] By Wm. Wallace, and supplied by the late Mr. John Young of Bearsden.

LIST OF SPECIMENS ANALYSED.

No.	Name of Seam.	Locality.	Description of Limestone.	*See* page
I.	Calmy	¼ mile E. of Darnley, and about 2 miles E. of Barrhead.	Middle of 10-ft seam. Light-grey, very fine-grained, with a cubical splintery fracture.	70
II.	,,	Spoil heap, old quarries, Robroyston	Light-grey, very compact and fine-grained, with cubical and splintery fracture	74
III.	,,	Caledonian railway cutting, near Provanmill	Light-grey, fine-grained, with a semi-cubical splintery fracture	74
IV.	Lyoncross	Cement Mine, Waulkmill Glen	Medium-grey, solid, fine-grained, with a slabby fracture	69
V.	,,	Near Cleuch, 500 yds. S.E. of Whitecraigs Station; left bank of stream.	Dark-grey, breaking into cubical blocks, with a semi-conchoidal fracture	203
VI.	Index	Left bank of White Cart, ½ mile north of Busby	Medium to dark-grey, fine-grained, with carbonaceous particles; splintery fracture	69
VII.	Hurlet	Sculliongour Mine, ¾ mile N. of Lennoxtown	Light-grey, more compact and fine-grained than VIII.; with a cubical and semi-conchoidal fracture	41
VIII.	,,	Hurlet Hill Plantation, Hurlet (Old Day-level)	Medium-grey, solid, encrinital	36
IX.	,,	Corrie Burn, ½ mile W.S.W. of Corrie	Dark-grey, very fossilferous, with a semi-splintery fracture	44
X.	,,	Limestone Mine, Cobbinshaw Loch, Midlothian	Locality in 1-inch Sheet 32. Analysis inserted for comparison	—
XI.	,,	Railway cutting, 60 yds. S.E. of road bridge, Auchinback, Barrhead.	Light-grey, fine-grained, fossiliferous, with cubical fracture	36
XII.	White Coral	Same as No. IX.	Highly fossilferous, white-grey, hard, cherty, coralline limestone.	29
XIII.	Ballagan Cement	Base of Main Cliff, Ballagan Spout, Strathblane	5-inch band. Light, buff-grey, with conchoidal fracture	11

COMPARATIVE TABLE OF ANALYSES

No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.
SiO_2 . . .	14·67	9·03	8·04	8·18	6·38	16·64	3·18	2·89	26·32	4·91	5·41	11·19	8·82
Al_2O_3 . . .	1·12	6·45	4·7	4·85	1·79	2·19	·84	3·75	4·57	4·44	1·05	·82	4·42
Fe_2O_3 . . .	1·54	2·4	2·19	9·34	11·6	1·5	1·20	1·73	1·68	3·16	1·54	1·01	1·55
MnO . . .	·37	·07	·11	·38	·41	·44	·03	·76	·72	·38	·19	·23	·47
CaO . . .	43·58	36·46	42·44	27·89	29·54	41·78	52·74	49·26	36·59	43·27	49·91	48·38	27·76
MgO . . .	1·71	7·39	4·36	11·31	11·37	2·15	·98	1·68	·85	2·75	1·51	·88	18·25
CO_2 . . .	36·34	38·22	38·75	38·26	39·58	34·88	41·37	39·51	29·69	40·81	40·68	37·85	39·14
H_2O . . .	·05	·01	·10	·02	·05	·15	·01	·01	·06	·05	·15	·01	·15
Totals . . .	99·38	100·03	100·69	100·23	100·72	99·73	100·35	99·59	100·48	99·77	100·44	100·37	100·56
Cementation Index[1] .	·95	·69	·60	·79	·61	1·14	·19	·26	2·11	·43	·33	·66	·57
$CaCO_3$ . . .	77·82	65·11	75·80	49·80	52·75	74·61	94·18	87·96	65·34	77·26	89·12	62·2	—
$MgCO_3$ . . .	2·59	15·52	9·16	23·76	23·88	4·51	—	3·58	1·79	5·77	3·17	—	—
$FeCO_3$ . . .	—	—	—	13·54	16·82	—	—	—	—	—	—	—	—

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[1] *See* p. 248.

extremely variable in thickness along the south side of the Arden basin. The Calmy or Arden Limestone was formerly worked at many localities in the Robroyston, Garnkirk and Bedlay districts, chiefly for use as a flux in iron smelting. South of the Clyde it is still quarried at Darnley, where it is about 10 ft. thick; the lower part of the seam is the better, the upper layers being argillaceous. The stone is burned on the spot and used for building and agricultural purposes. The line of old quarries along the outcrop of the bed is almost continuous, and it is unlikely that much more of the stone can be procured without mining.

R. G. C.

Certain limestones provide a natural cement and have been considerably worked for that purpose.

Of these the best known is the Orchard Cement, which has been quarried along the outcrop on both sides of Orchard, and eastwards to Williamwood. It was classed as a hydraulic or "Roman" cement, and used for sea walls and "wet" work of all kinds. The workings were discontinued through the competition of Portland Cement, which is stronger, sets more slowly and can be produced at the same cost.

The following analyses of the stone (I.) before and (II.) after calcining were made by Professor Frederick Penney, F.R.S., late Professor of Chemistry, Andersonian University, Glasgow:—

I.		II.	
$CaCO_3$	58·2	CaO	51·81
$MgCO_3$	7·5	MgO	5·68
$FeCO_3$	10·7	FeO	10·57
$MnCO_3$	0·4	Soluble Silica	17·03
Phosphates	0·8	Insoluble Silica	9·07
SiO_2	16·4	Al_2O_3 etc.	5·84
Al_2O_3	2·1		
Organic matter	2·8		100·00
K_2O and Na_2O	0·5		
Moisture	0·6		
	100·0		

E. M. A.

The Orchard Cement was also worked at Little Auchinback, near Barrhead, where it was of excellent quality. A trial was also made in the Waulkmill Glen, but the seam, though of good quality, measured only 6 in.—too thin for profitable working.

Further up the glen a small working was carried on in the Lyoncross Limestone of which only the lower part was mined. The product had the property of setting quickly, and was used for fireproof ceilings and for work between tide-marks; it was, however, of a deep ochreous colour, and had only half the strength of Portland Cement.

The well-known Calderwood Cement, so long worked near East Kilbride, occupies a position a few fathoms above the Main Hosie Limestone. It is the equivalent of the Top Hosie Limestone referred to in Chapter IV. In the sinking of the ironstone pit at Corkerhill, a cement of identical appearance was found in this position, and it is quite possible that a bed, similar in character, may occur in the Hurlet district, where the covering of superficial deposits is very slight. Trial borings along the east bank of the Levern Water, above the outcrop of the Main Hosie Limestone, should easily reach the position, but the area available is small, owing to the large fault which cuts off the beds to the south-west.

R. G. C.

ANALYSES OF LIMESTONES AND CEMENTS FROM THE AREA INCLUDED WITHIN THE GLASGOW DISTRICT MAP.

The analyses of a series of limestones and cements from the Glasgow district, carried out by the late Mr. J. S. G. Wilson for the first edition of this memoir, are given on pp. 244-245.

Method of Analysis.—In determining these limestones the method of procedure adopted was as follows :

1. Reduction of the material to an impalpable powder.
2. Heating the weighed portion over a Bunsen burner for one hour.
3. "Blasting" for ten minutes and dissolving out with hydrochloric acid.

By this method—applied to an ordinary limestone—all the different components with the exception of the silica were dissolved.

When the limestone was highly siliceous, hard and splintery, the weighed portion was first fused with Fresenius' flux, and the analysis then proceeded in the ordinary way. As pointed out by W. F. Hillebrand,[1] it is necessary, in order to ensure good accuracy in results, that the silica should be determined by two evaporations to dryness of the main solution ; while the alumina, iron, manganese, lime and magnesia were all reprecipitated *twice.*

The basic acetate process was used for the separation of alumina and iron from manganese. Water was determined by loss of weight in air-bath heated up to 200° C.

The carbonic acid was accurately determined by soda-lime absorption tubes. The average of three determinations (not varying more than ·02 per cent.) is stated.

NOTES ON ANALYSES.

Analysis I.—The CO_2 in this analysis will satisfy the whole of the lime and magnesia, leaving a small percentage (·21) possibly in combination with the iron.

The greater portion of the silica will be present as free silica.

Analysis II.—This analysis differs from that of the same seam at Darnley (No. 1). It is lower in silica and lime, and higher in iron and alumina and magnesia. The CO_2 will satisfy the whole of the lime and magnesia less ·32 per cent. The rest of the constituents are probably more or less in combination, leaving little free silica.

Analysis III.—The CO_2 here will satisfy all the lime and magnesia, and a portion of the iron. If the silica and alumina are in combination there will be little free silica.

Analysis IV.—The CO_2 satisfies all the lime and magnesia and $\frac{2}{3}$ of the iron. The probable combination of the rest of the constituents will leave little free silica.

Analysis V.—The CO_2 satisfies all the lime and magnesia and $\frac{9}{10}$ of the iron. A little free silica is probably present.

Analysis VI.—The CO_2 satisfies all the lime and the magnesia less ·21 per cent. In this limestone there must be a considerable percentage of free silica.

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[1] 'Analysis of silicate and carbonate rocks,' *Bulletin* 305. *U.S. Geol. Survey,* 1907.

Analysis VII.—The CO_2 satisfies the lime less ·07 per cent. It is a fair assumption that the alumina, iron, manganese and magnesia are in combination with a certain percentage of the silica, leaving about 1½ per cent. of silica free. Note the low Cementation Index.

This is a very pure Limestone—almost = Calcite.

Calcite.	Hurlet Limestone.
56 per cent. CaO	52·74 per cent. CaO
44 per cent. CO_2	41·37 per cent. CO_2

Analysis VIII.—The CO_2 in this analysis satisfies the lime and the magnesia less ·49 per cent., so that there can be little if any free silica to the sample.

Analysis IX.—The CO_2 in this analysis will exactly satisfy both the lime and magnesia.

$$\begin{array}{lrlr} \text{CaO} = & 36{\cdot}59 = & \text{CaCO}_3 & 65{\cdot}34 \\ \text{MgO} = & {\cdot}85 = & \text{MgCO}_3 & 1{\cdot}79 \\ \cline{2-2} \text{CO}_2 = & 29{\cdot}69 & & \\ \cline{2-2} \cline{4-4} & 67{\cdot}13 & & 67{\cdot}13 \\ \cline{2-2} \cline{4-4} \end{array}$$

In this sample the alumina, iron, manganese, and a small percentage of the silica will be in combination, leaving a large percentage of silica free.

Analysis XI.—All the CO_2 will satisfy the lime and magnesia less ·21 per cent. The rest of the constituents will be in combination, leaving a small percentage of the silica free.

Analysis XII.—The CO_2 does not satisfy the lime by 16 per cent. As the percentages of alumina, iron, manganese and magnesia are very small, the major portion of the silica will be free.

CLASSIFICATION OF LIMESTONES.

All limestones when calcined yield various limes, plasters, cements, etc., and these Eckel[1] divides into various groups.

(1) High Calcium Limes—containing less than 5 per cent. of magnesia.
(2) Magnesian Limes—containing over 5 per cent. of magnesia.
(3) Feebly Hydraulic Limes with Cementation Index from ·30–·70.
(4) Eminently Hydraulic Limes with Cementation Index from ·70–1·10.
(5) Natural Cements with Cementation Index from 1·00–2·00.

Cementation Index.—The Cementation Index of any limestone is obtained by the following formula :—

$$\text{Cementation Index} = \frac{\begin{array}{l}(2{\cdot}8 \times \text{percentage of silica}) + \\ (1{\cdot}1 \times \text{percentage of alumina}) + \\ (\ {\cdot}7 \times \text{percentage of iron})\end{array}}{(\text{percentage CaO}) + (1{\cdot}4 \text{ percentage MgO})^{2}}$$

The limestones within the Glasgow district which have been analysed, show a remarkable range in their various constituents, and in order to obtain the best *economic value* of these analyses, they are arranged first under groups 1 and 2.

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[1] 'Cements, Limes and Plasters,' New York and London, 1905.

[2] *Op. cit.*, p. 170.

Next, in order to show their further *economic possibilities*, they are placed under groups 3, 4 and 5.

This classification (analytical) has been determined by a due consideration of the various constituents of each individual sample along with its Cementation Index.

Group No. 1.—High Calcium Limes.

No.			Cementation Index.
I.	Calmy Limestone, Darnley		0·95
II.	,, ,,	Robroyston	0·69
III.	,, ,,	near Provanmill	0·60
VI.	Index Limestone, Busby		1·14
VII.	Hurlet Limestone, Sculliongour		0·19
VIII.	,, ,,	Hurlet Hill	0·26
IX.	,, ,,	Corrie	2·11
X.	,, ,,	Cobbinshaw Loch	0·43
XI.	,, ,,	Auchinback	0·33
XII.	White Coral Limestone, Corrie		0·66

NOTE.—No. II., although it contains 7·39 per cent. MgO is included in this list as the sample was taken from an old spoil heap.

Group No. 2.—Magnesian Limes.

IV.	Lyoncross (Cement) Limestone, Waulkmill Glen		0·79
V.	,, ,, ,,	Whitecraigs	0·61
XIII.	Ballagan Limestone, Ballagan Spout		0·57

In order to show their *hydraulic possibilities*, the above limestones are further arranged under the three following groups 3, 4, 5.

Group No. 3.—Feebly Hydraulic Limes.

No.		Cementation Index.
XI.	Hurlet Limestone, Auchinback	0·33
VII.	Hurlet Limestone, Sculliongour	0·19
VIII.	Hurlet Limestone, Hurlet Hill	0·26

These are very similar to the hydraulic lime of Holywell, England :—[1]

	Holywell.
SiO_2	5·0
Al_2O_3 Fe_2O_3	4·23
CaO	48·65
MgO	1·86
CO_2	40·26
Cementation Index = ·35	

English hydraulic limes of this type often serve as a basis for making selenitic limes.

X.	Hurlet Limestone, Cobbinshaw		·43
III.	Calmy Limestone, near Provanmill		0·60

This limestone was at one time wrought for hydraulic lime. It was classed as a "Roman Cement" (Summary of Progress for 1905, p. 129), but is not so (good Roman cements have a Cementation Index of 1·20–1·60). It is a good type of a feebly hydraulic lime.

IV.	Lyoncross (Cement) Limestone, Waulkmill Glen		0·79
V.	,, ,, ,,	Whitecraigs	0·61

Had these two Lyoncross Limestones contained less iron and magnesia, they would have furnished an "Eminently hydraulic lime." At Waulkmill Glen the cement produced was used for fireproof floors, etc., but on account of the large percentage of magnesia and iron present, it had only half the tensile strength of Portland Cement.

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[1] Eckel, *op. cit.*, p. 187.

Group No. 4.—Eminently Hydraulic Limes.

I. Calmy Limestone, Darnley . . . . 0·95
II. „ „ Robroyston . . . . 0·69

No. I. approaches very closely to the average of 19 analyses of the *best type* of hydraulic limestones used at the large cement-works at Zeil, France.[1] No. II., Robroyston, has also been placed under this class. The analysis is below that of an "Eminently hydraulic lime," but the sample was taken from an "old spoil heap," and it is possible that if a sample could be obtained from the rock face it would give results approximately the same as No. I., Darnley.

Group No. 5.—Natural Cements.

VI. Index Limestone, Busby . . . . 1·14

This limestone is very similar in composition to the rock from which "Natural Portland Cement" (*Not Artificial*) is made in Belgium. A comparison of the two is given (condensed).

Belgian Limestone.		Index Limestone.	
SiO_2	15·75	SiO_2	16·64
Al_2O_3	3·95	Al_2O_3	2·19
Fe_2O_3	1·00	Fe_2O_3	1·5
CaO	43·10	CaO	41·78
MgO	0·49	MgO	2·15
CO_2	35·21	CO_2	34·88
Cementation Index = 1·12[2]		Cementation Index = 1·14	

XIII. The Ballagan Cement is of no economic value, on account of the thinness of the beds in which it occurs.

The percentage of silica in No. IX.—Hurlet Limestone, Corrie—is so high that the stone represented by this sample is probably of little economic value compared with the Hurlet Limestone from other parts of the district.
J. S. G. W.

2. Setts and Road-metal.

No very large sett-making or road-metal industry exists within the Glasgow Sheet, the Kilsyth Quarries lying for the most part beyond its eastern boundary.

Several small quarries are worked for road-metal in the volcanic traps of the Campsie and Kilpatrick Hills. Among these may be mentioned Katiethirstie and Craigend Quarries, lying some distance to the west and south-west of Strathblane respectively. Some old road-metal quarries also occur in the volcanic rocks of the same age which form the Cathkin Hills. Of these, Cathkin Quarry (close to Westhills) is the largest; it was wrought in a porphyritic basalt of the Dunsapie type. A small quarry was in operation at a later date close to Carmunnock, in a porphyritic basalt more nearly approaching the Markle type.

The intrusive sills of teschenitic olivine-dolerite found in various parts of the Sheet, supply both setts and road-metal. Of these, Cranhill Quarry near Shettleston may be taken as an example. This quarry furnishes setts, cubes, flats and road-metal, the last being all hand-broken. The jointing is so distant that flats over 2 ft. in length can be obtained. It is noticeable that the structure described as "reed," which is so constant a feature of the quartz-dolerites of the Kilsyth district, is here absent, and the rock can consequently be broken with equal ease in all directions. Orchard Quarry, Gartcraig, near Glasgow, and Firpark Quarries, Golfhill, in the Necropolis sill within the City limits, are in intrusions of a similar nature. Both localities furnish setts, kerbs, road-metal and chips for concrete. The Provanmill Road Quarry, Glasgow, is only worked for road-metal, and is in a thin sill belonging to the same group of intrusions.

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[1] Eckel, *op. cit.*, p. 176.

[2] Eckel (*op. cit.*, p. 215) says of the above analyses of the Belgian rock, "It will be seen that if rock of the composition represented by the above analysis could be steadily obtained it would certainly be an excellent mixture for a Portland Cement. In composition it is admirable, while its cementation index is about that of the average commercial Portland."

A large number of important sett quarries have been opened in the Kilsyth district in the sills of quartz-dolerite intruded above and below the Index Limestone. Craigroot Quarry, at Queenzieburn, north of Gavell, is probably the only one of those at all recently wrought which lies within the limits of the Glasgow District Map. Setts, cubes and flats were produced, but the jointing was too close to permit the formation of kerbs. The "refuse" was broken up into road-metal, mostly by means of a Baxter crusher. The following remarks as to directions of cleavage apply equally well to the other quarries in the Kilsyth district. There are two sets of parallel planes in the rock along which it will split most easily. These are at right angles to each other, and are both perpendicular to the surfaces of the sill.[1] One of these is more pronounced than the other, and is called the "flat," while the other is the "hem." In order to take full advantage of this fissile character, it is necessary to strike the stone from a direction which is parallel to the intersection of these two sets of planes. Thus, in the case of a nearly horizontal sill such as that of Craigroot, if a block be placed in the position which it naturally occupies in the quarry (or upside down), and struck from above, it will split easily, but if placed in any other position it will not split so easily, even along the "flat." A somewhat similar phenomenon occurs in the case of slate quarries, where, to get the full advantage of the cleavage, the blocks must be split from one particular side. These peculiarities are well known to the quarrymen, and are of great importance in shaping setts and other material of this kind. The two sets of planes are termed the "reed" of the rock. Setts are placed in the streets with the "reed" vertical, and their long direction is parallel to the "flat," which runs nearly east and west in the case of Craigroot Quarry.

The machine-broken rock from Craigroot, like that from most of the other dolerite quarries, was riddled to five different sizes. The two largest consisted of material 2 in. and 1½ in. in diameter; these were used for road-metal. Then came "chips" measuring about half an inch, "peas" which were still smaller, and "dust." The three last varieties were used for the binding of roads. Chips and peas were also used for gravel-walks, and the dust for cement.

Claddens Quarry is in an east-and-west dolerite dyke which traverses Carboniferous Limestone strata near Bishopbriggs, and was wrought for setts, cubes and road-metal; the rock is a quartz-dolerite and probably of the same general age as that of the Kilsyth quarries.

External Sources of Supply.—The setts used for paving the streets of Glasgow are partly dolerite from the Kilsyth quarries, and partly of a class known as "granite," though it must not be forgotten that the trade definition of granite includes species not so classed by geologists.

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[1] Perhaps it might be more correct to say that the rock will split easily along any plane which is perpendicular to the surfaces of the sill.

As a general rule, granite (in the wider sense) is used for main streets and places where the traffic is heavy, and dolerite for side streets where it is light.

The two main sources of "granite" used by the Master of Works' Department are :—

(1) Bonawe Quarry, Loch Etive.
(2) Furness Quarry, Loch Fyne.

The former is a true biotite-granite of Old Red Sandstone age, forming part of the Ben Cruachan complex.[1] It is, however, of finer grain than most of the Ben Cruachan granite, and this fineness of grain is probably an important feature as regards durability, as certain coarser granites have been tried with but indifferent results. The latter is in reality a quartz-porphyry, in which porphyritic crystals of quartz, felspar, hornblende and brown mica are set in a fine-grained matrix.[2]

The Tramways Department uses the above-mentioned granites, but obtains a larger supply from Carnarvon. Setts formed from the riebeckite-granite, or riebeckite-eurite of Ailsa Craig have recently been used in the extension of the tramways line between Canniesburn and Milngavie. Swedish and Norwegian granites have also been tried, in at least one instance with good results.

Caithness flags were formerly much used in Glasgow for the paving of side walks. They were, however, found to be too slippery for steep slopes, for which purpose Arbroath flags were preferred. On certain specially steep gradients, such as Balmanno Street and some streets in Garnethill, ordinary sandstone from Corncockle Quarry in Dumfriesshire was at one time put down. E. M. A.

3. Building Stones, Moulding and Building Sand, and Refractory Sandstones.

(i) Account, from a stratigraphical point of view, of the sandstones of economic value within the Glasgow Sheet.

(ii) Building-stones from external sources chiefly employed in Glasgow.

(iii) Physical and microscopical characters and weathering qualities of sandstones.

(i) Among local building-stones, by far the largest part are sandstones of Carboniferous age, and especially those belonging to the Carboniferous Limestone Series. The Calciferous Sandstone, which furnishes so many well-known building-stones in the east of Scotland, is comparatively little used in the Glasgow neighbourhood. For purposes of description the different horizons may be included under the following groups :—

A. Lower Old Red Sandstone.
B. Calciferous Sandstone Series.
C. Limestone Coal Group. } Carboniferous
D. Upper Limestone Group. } Limestone Series.
E. Millstone Grit.
F. Lower or Productive Coal Measures.
G. Barren Red Measures.

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[1] 'The Geology of the country round Oban and Dalmally,' *Mem. Geol. Surv.*, 1908, p. 173.

[2] 'The Geology of Mid-Argyll,' *Mem. Geol. Surv.*, 1905, p. 154.

A. *Lower Old Red Sandstone.*—This formation supplies the local building material in the neighbourhood of Killearn, but it is not quarried on a large scale within the Glasgow district.

B. *Calciferous Sandstone Series.*—Comparatively few quarries of any importance have been worked in the Calciferous Sandstone Series within the area. A massive white sandstone lying at the junction of the Upper Old Red Sandstone and Cementstone Groups has been quarried on a small scale at several points along the course of the Loch Katrine aqueduct north of Strathblane. There are several abandoned quarries in the thick Craigmaddie Muir Sandstone to the east of Craigend Muir, and one on the same horizon has been worked to the north of Milngavie (Craigash Quarry, *see* p. 262). A sample of stone from this quarry is white in colour, and somewhat hard and fine-grained in character.

C. *Limestone Coal Group.* — Building-stone has been obtained from at least three horizons within this group. At Eastpark Quarry in the Kelvinside district of Glasgow, two sandstones were formerly worked immediately above and below the Knightswood Gas Coal. South of the Clyde the upper of these sandstones is the better developed, and was formerly quarried at Craigton, south of Govan. It is a brownish sandstone, probably too coarse to form a good building-stone, and in places full of plant remains.

At the old Nitshill Quarry, near the village of that name, two posts of sandstone were quarried. The lower of these was 17 ft. in thickness and of good quality, while the upper was a poorer stone, and separated from the lower by a certain thickness of strata. The lower post was consequently worked to a certain extent by mining. Its position lay between the Stone Coal and the Two-feet or Satturland Coal.[1]

D. *Upper Limestone Group.*—The most productive quarries in the Glasgow district fall within this group, and have been opened on two horizons. These are—(1) the sandstone immediately above the Index Limestone, and known in the district south of the Clyde as the Barrhead Grit. North of the Clyde it is known as the Bishopbriggs Sandstone,[2] from the locality where it has long been worked. A sandstone is persistent at this horizon through a great part of the central valley of Scotland, and is known near Edinburgh as the Joppa Sandstone. (2) The sandstone that lies above the Lyoncross Limestone, and is known as the Giffnock Sandstone. This bed has only been wrought to any extent in the neighbourhood of Giffnock, and is impersistent.

In the south-western corner of the Glasgow Sheet, where the Barrhead Grit has its typical development, there are many deserted quarries, but none that were worked on any large scale, the material being too coarse for a good building-stone. It was also quarried just above the outcrop of the Index Limestone at Cowglen, but here again the sandstone is gritty or even pebbly in character. At Huntershill Quarry, Bishopbriggs (*see* p. 262), the character of the rock is entirely different, being fine to medium in grain. The workings at this quarry were in 1908 entirely underground, forming galleries 50 ft. in height, which present an imposing spectacle. The process of quarrying was started by a special set of "miners," who drove in horizontal mines near the top of the post. Quarrymen then wrought downwards from these mines, a few feet of solid sandstone being left above to support the roof. The whole of the rock obtained was white except a few feet at the top, which were yellow in colour, but were said notwithstanding to be rather superior to the remainder in weathering qualities. One feature of the quarry is the thickness of some of the beds, which, together with the absence of joints, makes it possible to obtain blocks of very large size. A serious fall of the roof of the mine in 1908 caused the abandonment of the workings.

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[1] 'New Statistical Account of Scotland,' vol. vii., 1845, Renfrewshire, p. 153.

[2] The Bishopbriggs Sandstone corresponds strictly to the lower part of the Barrhead Grit.

Most of the stone was used in Glasgow and down the Clyde valley. Some, however, was shipped to Belfast. The older portion of the Glasgow University buildings, Gilmorehill, is partly of this stone and partly of stone from Giffnock, as the two are so similar in appearance as to be interchangeable. Another example of a building from Huntershill Quarry, as well as examples from the various quarries hereafter referred to, will be found in the list which concludes this section.

The disused Kenmure and Coltpark quarries, on the opposite side of the railway from that last referred to, are on the same horizon, and formerly furnished a considerable supply of stone to Glasgow. The old quarries at Netherton of Garscube are also very probably in this sandstone. Roseneath House, Garscube House, and Blythswood House are built from these, and the stone was exported at one time to Ireland, and even to the West Indies.[1]

The Queenziemill Quarry (*see* p. 261), three miles north-east of Kirkintilloch, is in the Dullatur Sandstone, which is also equivalent to the Bishopbriggs. The upper part of the rock is slightly yellowish, followed by 45 ft. of white stone in thick beds free from joints, for which the quarry was mainly wrought. The base of this sandstone is only a short distance above the dolerite sill, which was worked at Craigroot Quarry, immediately to the north, and it is noticeable that the intrusion has had no appreciable effect on the quality of the sandstone. The stone was formerly used in Glasgow, and Fort William station is built from it.

The largest source of supply within the Glasgow district was for many years the well-known Giffnock quarries. Near Giffnock almost the entire thickness of strata between the Lyoncross and Orchard Limestones consists of sandstone. Only the lowest 60 ft. of this, however, has been worked to any extent, and the term "Giffnock freestone" is confined to the bottom layer of "Liver" rock, 16 to 30 ft. in thickness. The quarries follow a line of outcrop in a west-north-westerly direction for about a mile, the beds being inclined at a very gentle angle to the south. In the Braidbar and New Braidbar quarries the section (now partly obscured) consisted of 30 ft. of "Moor rock" resting on 30 ft. of "Liver rock." The former is a somewhat porous sandstone, of less value than the underlying stratum, for which the quarries have been mainly opened. A liver rock, as the name implies, is one in which no bedding is apparent, and which can be worked with equal ease in all directions.

These Braidbar quarries are remarkable for the extent to which the Liver rock has been mined, in order to avoid removing the cover of inferior sandstone, etc. The two quarries lie about 1000 ft. apart, separated by a low hill which has been completely undermined by galleries, and mining has also been carried on to the south of the two quarries. Broad stoops or pillars have been left for support between the galleries, which are about 30 ft. in height.

In the Giffnock (*see* p. 262) and other quarries further to the west, the section is similar to that already described, but the Liver rock is thinner, and the post above it is termed "Grey rock," being different in certain respects from the Moor rock of the Braidbar quarries. The sandstone appears again between Bogton House and Hillhead, about half a mile to the north of its main outcrop, being presumably brought up by a fault. Several quarries have been opened along this outcrop at one time or other, but the character of the stone is markedly inferior, the valuable Liver rock of the southern quarries being absent. The quarrymen stated that the latter had a very limited extension, thinning out also in the underground workings to the south of the Braidbar quarries.

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[1] 'New Statistical Account of Scotland,' vol. viii., 1845, Dumbarton, p. 57.

The largest market for the stone was naturally in Glasgow, and a very large number of buildings in the City consist of material from these quarries, more especially south of the river. Examples of its application will be cited in the list at the end of the section. A certain trade was also done with Belfast, and some of the finer Liver rock has been exported to America and South Africa for building and monumental purposes. The quarries are at present disused.

No large building-stone quarries have been opened in the strata between the Calmy and Castlecary Limestones. A sandstone a little above the former position is, however, worked in the Avenuehead and Drumcavel quarries (*see* p. 260), east of Chryston, and ground down into moulding sand. For this purpose it is necessary that the quartz grains should be imbedded in a clayey matrix, which binds them together after the mould has been formed. The sandstone in question has this character (*see* microscopic description, p. 260). There is also present some material which, when weathered, produces abundant limonite. As a result, the stone nearest the surface in both quarries is tinged a bright yellow colour, and has somewhat different properties from the rock beneath. The white rock forms the more suitable sand for heavy castings, while the yellow answers well for mouldings of a lighter character. The market is mainly for foundries in the Glasgow neighbourhood, but some of the sand is sent to England and Ireland, and occasionally abroad.

E. *Millstone Grit.*—Like the upper division of the preceding group, the Millstone Grit of the Glasgow district supplies no building-stones, but contains sandstones which, when ground down, yield a sand suitable for moulding purposes. A sandstone 40 or 50 ft. in thickness, lying a short distance above the Garngad Road Cement,[1] is wrought for this purpose in the Garngad Quarry near Germiston House.

At Blochairn Quarry (*see* p. 259), near the Alexandra Park, which is probably on a somewhat higher horizon, the section is as follows :—

Hard white sandstone . . .	20 ft. }
Soft white sandstone . . .	30 ft. }
Dark blaes with thin coal	

The top 20 ft. is entirely different in nature from the remaining rock in the quarry (*see* microscopic description), and is a sandstone of refractory character formerly used for forming the bottoms of heating furnaces in steel works and forges. The lower 30 ft. is an argillaceous sandstone, and was ground down for moulding sand. For the finer class of castings the sand was used as a "green sand" without admixture. For heavier castings it was mixed with a little fireclay, moulded in a wet condition, and then dried in ovens, being known in this condition as a "dry sand."

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[1] *Cf.* pp. 84-5.

The rock from the abandoned Germiston Quarry (*see* p. 260), north of Germiston House, was ground down and used partly as a moulding and partly as a building sand.

Certain beds of refractory sandstone, used for silica brick, also occur in the Millstone Grit of this district, and are referred to in another chapter (p. 87).[1]

F. *Lower or Productive Coal Measures.*—The lowest building-stone horizon of any importance within this group is that of the Kirkburn or Homehills Quarry (*see* p. 262), south of Cambuslang, which was opened in a sandstone 35 ft. thick, only a foot or two above the old waste of the Humph Coal. As a result of its position no water was met with, but cracks had been produced, especially in the lower part of the sandstone, which somewhat interfered with the working of the quarry. The rock as a whole is a white sandstone of superior quality, and was all dressed into blocks; hence no explosives could be used in the extraction. The refuse was riddled, and the siftings employed for building sand and in the making of concrete. The stone was in demand locally, and also in some parts of Glasgow.

A sandstone was worked at Budhill Quarry, just south of Shettleston station, at a distance of about 12 fms. above the Ell Coal. It is 40 ft. thick, and all the lower part was used for building, while the upper 8 or 10 ft. were mined to some extent for moulding sand. The whole rock has an argillaceous matrix, but this is less marked in the harder portion used for building stone.

A sandstone was formerly quarried at Braehead, one and a half miles east of Baillieston, in a position above the Upper Coal and below Skipsey's Marine Band. It seems to form a constant horizon, and has been worked elsewhere outside the Glasgow Sheet. It is, however, somewhat soft and false-bedded in character, and would not probably furnish a very good weathering stone.

G. *Barren Red Measures.*—The sandstones in this division of the Coal Measures are characterized by irregular staining due to haematite. It is this variation in colour, rather than any defect in weathering qualities, which has restricted their use in Glasgow largely to inside work. Where the colour is uniform the rock may form a quite satisfactory building-stone for other purposes. Among the most important of these reddish sandstones is that which was worked at Eastfield, west of Cambuslang (*see* p. 262). There is here 60 ft. of sandstone; the upper part contains galls of clayey haematitic matter, which are surrounded by deep red haloes, but these are almost absent from the lower portion of the quarry, which in consequence can be used for a superior class of work. It is not quite certain whether this rock is actually within the Barren Measures, as it lies only about 40 fms. above the Ell Coal. This doubt does not apply to the stone of Bredisholm Quarry (*see* p. 262), one mile north of Uddingston. The finest rock from this quarry was used for ashlar fronts, and the stone was much employed in the town of Coatbridge, where Gartsherrie Public School may be given as an instance of its use. Both the Eastfield and Bredisholm Quarries are now disused.

The essexite intrusion to the north-west of Lennoxtown, which is described on p. 152, might possibly be of some value as an ornamental stone.

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[1] *See* also 'Special Reports on the Mineral Resources of Great Britain,' *Mem. Geol. Surv.*, vol. vi., Refractory Materials: Ganister and Silica-Rock, etc., 1918, p. 143.

(ii) SOURCES OF SUPPLY OUTSIDE THE AREA INCLUDED IN THE GLASGOW DISTRICT MAP.

The building-stones from external sources most largely employed in Glasgow are chiefly derived from Scottish Carboniferous strata, and from the Scottish "New Red Sandstone," probably mainly of Permian age. Another minor source of supply is the Upper Old Red Sandstone of Wemyss Bay, of which Ardgowan Terrace, Sauchiehall Street, has been built. Among the outside Scottish Carboniferous sources, those in the Calciferous Sandstone Series of the east of Scotland may first be cited. Examples are given in the list from Grange Quarry near Burntisland, and from the disused Humbie and Hermand quarries, Linlithgowshire. The first is the equivalent of the Dunnet Sandstone of the Lothians and lies at the base of the Upper Oil Shale Group; the two latter are on the horizon of the well-known Binny Sandstone. A supply was also formerly obtained from the quarry of Cullalo in Fifeshire, also coming within the limits of this group.

The Stirlingshire quarries in the uppermost group of the Carboniferous Limestone Series have also afforded an important supply of building-stone. Among these are Plean, Polmaise, and Dunmore quarries; the first is on a horizon equivalent to the Bishopbriggs Sandstone, while the two latter are on a somewhat higher level, beneath the Calmy Limestone. A large supply has been obtained from Overwood Quarry near Stonehouse, in a sandstone which overlies the Kiltongue Musselband, and is thus in the lower part of the Productive Coal Measures. Besides this, the most important quarries in the Productive Coal Measures are probably those of Auchinlea, near Cleland, between the Virtuewell and the Blackband Coals. Among the red sandstones of the Barren Measures may be mentioned that which is worked at Bells and Bothwell Park quarries, on opposite sides of the Caledonian (now L.M.S.) Railway near Bellshill.[1]

The Lower Carboniferous Sandstones of Northumberland, which are so much used in Edinburgh, have also been introduced into Glasgow. A stone which has been somewhat largely employed comes from the Blackpasture Quarry. It is a highly siliceous sandstone of a light yellow colour, and lies not far above the Great Limestone of the North Tyne. The Prudham Quarry stone, not far below the same limestone, is very similar in colour, and can be used together with the stone from Blackpasture, as has been done in the Post Office building in Waterloo Street.

There fall next to be mentioned the various building-stones which are classed under the convenient title of the "New Red Sandstone."[2] These are all red in colour, and are probably mainly Permian, though also partly Triassic, in age. The districts in which this sandstone has been quarried are three in number:

(1) Various localities in Dumfriesshire.
(2) The district of Mauchline in Ayrshire.
(3) Corrie in the island of Arran.

The principal Dumfriesshire quarries from which stone has been supplied to Glasgow are Locharbriggs, Closeburn, Corncockle, New

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[1] For a detailed account of these, *see* W. R. Smellie, 'The sandstones of the Upper Red Barren Measures to the east of Glasgow,' *Trans. Geol. Soc. Glasg.*, vol. xiv., part iii., 1913, p. 258.

[2] *See* Boyle, 'The Economic and Petrographic Geology of the New Red Sandstones of the South and West of Scotland,' *Trans. Geol. Soc. Glasg.*, vol. xiii., part iii., 1909, p. 344.

Cove and Gatelawbridge, while the two largest quarries near Mauchline are those of Ballochmyle and Barskimming. Of these it is probable that New Cove is Triassic in age, and that all the others are Permian.[1] The Cove quarries are in the Annanlea Sandstone, which has been included, along with certain other sandstones and marls, in the "Annan Series." The Annanlea Sandstone is a compact, light red rock, composed mainly of sharp, angular grains of quartz and felspar, with numerous flakes of white mica. The bedding is fairly regular. The other quarries are in different basins of the "Dumfries Series," to which the rock of the "Isle of Arran" quarry, near Corrie, also belongs. The sandstone of this group is much more false-bedded than the Annanlea Sandstone. It has certain physical and mineralogical characters which will be referred to later, and it contains practically no mica. The Ayrshire stone is said to be, on the whole, a little darker in colour, and more porous, than its Dumfriesshire equivalents.

The "New Red" sandstones as a whole form a very large source of supply, not only to Glasgow, but to all the Scottish Lowlands.

A new departure was made in 1909 in the adoption of Portland Oolite from Dorsetshire in the erection of the Northern Insurance Company's premises in St. Vincent Street. Some beds from this well-known horizon have good weathering properties and stand well in London. It will be interesting to see whether they can equally well withstand the test of a Glasgow atmosphere.

There remain only to be noticed the red granites employed in the City for shop fronts and ornamental purposes. The greater part of these are probably from Peterhead, but the red Ross of Mull granite has also been made use of. The base of the Municipal Buildings is formed of a red granite from Corrennie Quarry, Aberdeenshire.

(iii) CHARACTERS AND WEATHERING QUALITIES OF THE SANDSTONES.

In order to test the probable influence of the structure and composition of the building-stones of the Glasgow district on their power of resisting the action of the atmosphere, material from the following quarries was sliced, and has been examined under the microscope. The list includes several moulding sandstones and one refractory sandstone, which are interesting both in themselves and in comparison with the building-stones:—

	No. of Slide in Survey Collection.
Bredisholm Quarry (building sandstone)	13252
Drumcavel Quarry (moulding sandstone)	13730
Avenuehead Quarry ,, ,,	13732
Germiston Quarry ,, ,,	13821
Kirkburn Quarry (building sandstone)	13822
Queenziemill Quarry ,,	13823
Blochairn Quarry (moulding sandstone)	13824
,, ,, (refractory sandstone)	13825
Eastfield Quarry (building sandstone)	13826
Giffnock Quarry (Liver Rock) ,,	13727
Craigash Quarry ,,	13827
Huntershill Quarry ,,	13828

With regard to the clastic grains of which these sandstones are composed, quartz is in every case the dominant mineral; in all the building-stones it is accompanied by a few flakes of white mica. In all the Lower Carboniferous sandstones, felspar, if present, is very infrequent, and this applies also to the two sandstones from Blochairn Quarry in the Millstone Grit. In the sandstone of Germiston, however, which is on a somewhat higher horizon in the same series, and in the three sandstones taken from the Coal Measures, grains of felspar play a much more prominent part, though still subordinate in number to those of quartz. This must not be taken, however, as having any detrimental effect on the quality of the building-stone, because in the first place the felspar is all perfectly fresh, and in the second place it consists entirely of potash felspar (mainly microcline), which, as is well known, stands climatic influences better than do soda-lime felspars.

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[1] J. Horne and J. W. Gregory, 'The Annan Red Sandstones of Dumfriesshire,' *Trans. Geol. Soc. Glasg.*, vol. xv., part iii., 1916, p. 374.

The nature of the cementation has much more to do with weathering properties in ordinary cases than has the material of the clastic grains. The cements mainly present in the Glasgow district sandstones examined are—(1) quartz, (2) carbonates, (3) an irregular aggregate consisting partly at least of minute flakes of white mica, (4) a somewhat more regular aggregate consisting of kaolin.

To illustrate the mode in which the quartzose cement occurs, we may take as an extreme type in which it is present almost to the exclusion of any other mineral, the refractory sandstone of Blochairn. When a thin slice of this rock is examined under the microscope, the outlines of the quartz grains are seen to be extremely irregular. If they were in the condition in which they were originally deposited, it might be expected that each grain would be in contact with its neighbours at one or two points only. Instead of this, two grains are often seen to border each other closely for almost their whole length, fitting into each other's concavities and convexities as accurately as two sides of a tally. Such a condition could not have arisen by chance, and is the clearest evidence that the shape of the grains has been modified by the addition of secondary silica in crystalline continuity with the original grains. If further evidence were necessary, the outlines of previous states of the sand-grains are often indicated by lines of inclusions. Fig. 26 shows the relations of the grains as seen in the microslide. In this and the following text-figures the component minerals have been indicated by distinctive ornamentation. Blank spaces usually indicate pores.

The moulding sandstone in which the lower part of Blochairn Quarry is excavated is an extreme type of another sort, and it is curious that types of such opposite character should occur in such close proximity. Quartzose cement of the kind just described is not entirely wanting, as two grains may sometimes be seen to tally for a short distance. More often, however, they are separated by another cementing material which pervades the whole slide in great quantity. This consists of a felt-like aggregate of minute scales of some mineral with rather high refraction. As the double refraction is also high, showing sometimes blue of the second order in spite of the minuteness of the flakes—and as, moreover, the aggregate is colourless, and shows lowest refraction for rays perpendicular to the flakes—there can be no doubt that a large part of it consists of muscovite or white mica, though other flaky minerals may possibly be present.

A carbonate cement, tinted brown by oxide of iron, also occurs, but in smaller quantity, and a small amount of limonite is also present. Fig. 27 shows a part of the slide in which the grains of quartz are cemented by the micaceous aggregate.

The moulding sandstone of Avenuehead and Drumcavel presents features similar in some respects to that of Blochairn. In the present case the rock must have been laid down originally as a loose aggregate of grains of silica. Quartz began to grow round these grains in crystalline continuity, but stopped at an early stage. To this may be ascribed the fact that many of the quartz grains show crystal faces and corners, a feature hardly visible in the Blochairn refractory sandstone, where the process has been much more nearly completed. Neither is it common in the majority of the building-stones to be afterwards described. The spaces between the quartz grains are filled with a flaky aggregate, which gives on the whole a much weaker double refraction than the similar aggregate of the Blochairn sandstone. This is largely a consequence of the minuteness of the flakes, and it is evident that much of the aggregate consists as before of white mica. It is however impossible to say that there may not in this case be a more considerable admixture of other flaky minerals, and in particular kaolin. In part of one of the slides the cement is carbonate, to the exclusion of anything else. As there seems no other source for the limonite which occurs so abundantly in the weathered rock, it is probable that this is partly carbonate of iron, a supposition which is strengthened by a simple qualitative test.

Yet another form of cement is present in the moulding sandstone of Germiston. In this case also, a certain amount of secondary silica is present. There is, however, in addition, a large amount of a flaky aggregate which differs from the micaceous aggregate already described partly in its lower birefringence and partly in the arrangement of its flakes. These are superposed in a regular manner, so as to form bundles which are sometimes parallel, but have generally a more or less radial arrangement. The radiation may cover as wide an angle as 180°, and as the extinction is nearly straight, may result in one or two arms of a black cross being visible under crossed Nicols. This peculiarity is, however, perhaps better seen in some of the other slides examined, in which the aggregate is present. To determine the nature of the mineral, some of the sandstone was crushed and the material of the cement concentrated by using a heavy liquid of Sp. Gr. 2·677, which floated the quartz grains and potash felspar, but allowed the flaky aggregate to sink. By this means it was found to consist of hexagonal flakes arranged in the bundles just described. (*See* Fig. 30.)

The latter have thus the form of straight or curved hexagonal prisms, and resemble exactly the figures given by Hickling for the kaolin of the Cornish china-clays.[1] The lowest refractive index is for rays parallel to the axis of the prism, and agrees almost exactly with that of an oil with R. I. 1·561. The amount of double refraction may be estimated roughly by measuring the transverse dimensions of the prisms, and then, while they are in the same position, determining the retardation by its effect on the sensitive violet of a selenite plate. If we assume that the prism-sections are regular hexagons, this method gives a maximum double refraction of about ·006. If the hexagons are irregular, it is probable that the prisms rest on their broadest faces, and this value may have to be a little increased. In any case there is approximate agreement with the figures given for kaolinite by Mr. Allan Dick,[2] especially as to the value of the single refraction. An exactly similar cementing material was separated from the Kirkburn Sandstone to be shortly described, and it was found that the plates retained their hexagonal outlines after boiling for an hour in strong hydrochloric acid. This fact excludes halloysite, and makes it practically certain that the material is kaolin.

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[1] 'China-clay, its Nature and Origin,' *Trans. Inst. Min. Eng.*, vol. xxxvi., 1909, p. 10.

[2] 'Supplementary notes on the mineral Kaolinite,' *Min. Mag.*, vol. xv., p. 124.

What is characteristic of all these moulding sandstones is the presence, in the form of a cement, of an unusually large quantity of some fine flaky aggregate. This, as we have seen, is largely mica in three of the quarries considered, and in the remaining case, kaolin. It is this flaky material which gives the sand the consistency necessary to form moulds. On the other hand, its presence in so large a quantity would be detrimental to the stone if any attempt were made to use it for building.

In smaller quantity some such cement would seem to form no unusual features in sandstones used for this purpose, as it is present in the whole of the building-stones examined. It is, no doubt, what has been very frequently described as a "clay" cement, no attempt having in general been made to determine the exact nature of the minerals forming the clay.[1] Leaving the presence of carbonates out of account, these stones may be looked upon as members of a series of which the one end is represented by such sandstones as the refractory sandstone of Blochairn above described, while the other is formed by the moulding sandstones. A sandstone with the amount of siliceous cement present in the first-named rock would almost certainly form a good weathering stone, but its extreme hardness would probably make the cost of working prohibitive.

On the other hand, a moulding sandstone is soft and incoherent, and would very soon be injured by frost, even if it were capable of standing the strains involved in building operations.

According to its place in this series, a building-stone may therefore be expected to approximate in quality either to one type or to the other. A building-stone with much siliceous cement generally weathers well, but is hard to work, while one with a large proportion of a cement formed by a flaky aggregate of either sort, is likely to be easy to work, but to resist frost badly. It is also likely to have a much less compressive resistance than a more siliceous type. This, however, is not in general in itself important, as under ordinary circumstances the strains necessary to produce fracture even in the class of sandstones referred to do not arise. It may, however, be of importance as forming a rough indication of probable weathering powers.

The above remarks refer to stones of the limited class only in which the two above-mentioned sorts of cement play the leading role. Considerations of quite another sort arise from the presence of carbonates. White mica is not attacked by either hydrochloric or sulphuric acid. Kaolin is only slowly attacked by boiling sulphuric or boiling hydrochloric acid. There seems, therefore, little likelihood that either of these constituents is differentially affected by a city as compared to a country atmosphere. Their weakness probably lies in their susceptibility to the mechanical action of percolating water and of frost. Carbonates, on the other hand, are readily affected by these acids, and a stone which contains them in quantity may therefore be expected to stand best in country situations.

The sandstone of Queenziemill Quarry furnishes the only instance in the district in which a micaceous aggregate plays an important part in the cementation of a building-stone. In this case the quartz grains have grown until they are very largely in contact, but interspaces are left which are filled up by the cement in question. An aggregate of tiny flakes, having an arrangement and appearance exactly resembling that seen in the moulding sandstone of Germiston, is, however, a much more common feature, and occurs in stone from Huntershill, Giffnock, Kirkburn, Eastfield and Bredisholm. In the case of Kirkburn (Fig. 28) the material has been separated, and identified as kaolin by means of its form and optical characters in the way already described. There can be no doubt that in the other cases we are dealing with the same material. In the Kirkburn sandstone the flakes are somewhat larger than usual and measure up to 70 or 80 μ across.[1] For comparison it may be mentioned that the sand-grains vary from 150 to 600 μ in length.[2]

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[1] *See*, however, Kaiser, 'Ueber Verwitterungserscheinungen in Bausteinen. I.' *Neues Jahrbuch*, 1907, Bd. II., p. 42, and Lang, 'Ueber Kaolinit in Sandsteinen des schwäbischen mittleren Keupers,' *Centralblatt für Mineralogie*, etc., 1909, p. 596.

In all the sandstones mentioned the quartz grains have increased in size, and border each other in places as before described. A certain amount of carbonate is also present in every case. Kaolin, however, together with the additional quartz, forms the preponderating cement in the stone from Kirkburn, Eastfield and Bredisholm quarries. In the sample from Huntershill the amount of kaolin is approximately equal to the amount of carbonate, while in the Giffnock Liver rock (Fig. 29) the carbonate is in excess. It is interesting to compare the analyses given below of the Giffnock Liver rock, and of stone from Huntershill and Bredisholm quarries (Analyses I., II., and IV., p. 264), with their character as shown under the microscope. The alumina present in every case, except possibly Bredisholm, is mainly due to the kaolin. In two cases at least, to judge from other analyses which have been published,[3] the oxide of iron would seem to be partly due to the presence of ferrous carbonate.

Among the samples of building-stone examined, that of Craigash Quarry has the greatest proportion of siliceous cement. A certain amount of limonite is, however, also present, and even in this case kaolin is not entirely wanting.

A word may next be said as to the physical and chemical characters of the probably Permian part of the "New Red" sandstones so largely used in Glasgow. They are generally less compacted, and consequently more porous than Carboniferous sandstones, a feature possibly due to their more recent geological age. Their porous character would in itself be almost certainly detrimental to their weathering qualities, were it not counterbalanced by the more than usually favourable nature of the cement. Analyses of the stone show in certain cases as much as 96 or 97 per cent. of silica. Carbonates are almost wanting, and, curiously enough, there is frequently less than 1 per cent. of oxide of iron. The latter substance is most probably present in the form of hæmatite, or as one of the mineral species intermediate between hæmatite and limonite, and gives its characteristic red colour to the stone, although present only in the merest films coating the original rounded grains of which the sandstone is composed. In the case of the stone from Locharbriggs, additional quartz has grown outside these films in crystalline continuity with the interior grains.

The opinion advanced by Dr. Wallace[4] that the presence of car-

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[1] About $\frac{1}{350}$ inch.

[2] $\frac{1}{160}$ to $\frac{1}{40}$ inch.

[3] J. Wallace Young, 'On the Chemistry of some Carboniferous and Old Red Sandstones,' *Trans. Geol. Soc. Glasg.*, vol. ii., 1867, p. 198.

[4] 'On the Decay of Building Stones,' *Proc. Phil. Soc. Glasg.*, vol. xiv., 1883, p. 22.

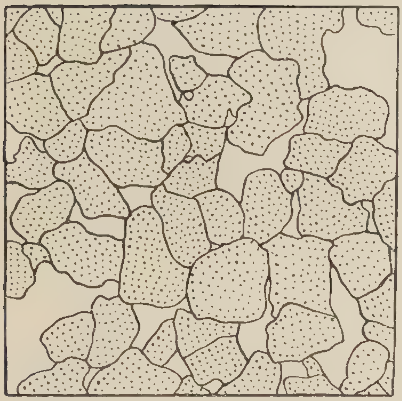

FIG. 26.—Blochairn Refractory Sandstone × 34.

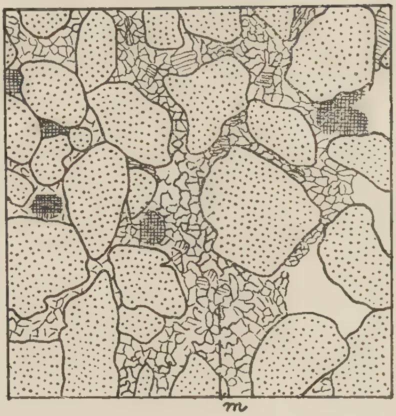

FIG. 27.—Blochairn Moulding Sandstone × 90. m = Micaceous Aggregate.

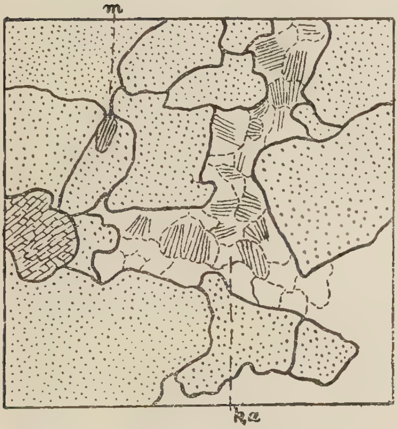

FIG. 28.—Kirkburn Sandstone × 100. m = Muscovite; ka = kaolin.

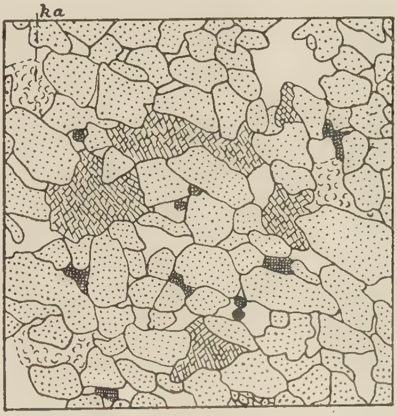

FIG. 29.—Giffnock Sandstone × 34. ka = kaolin.

░ Quartz grains.

▨ Calcite.

▓ Opaque material, mainly Limonite.

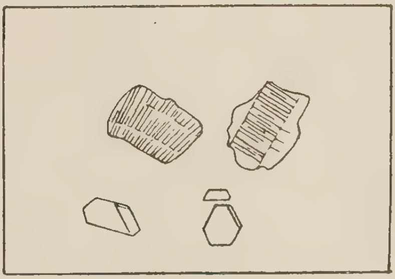

FIG. 30.—Kaolin from Germiston Sandstone × 450.

bonates improves the weathering power of sandstones may in a certain very limited way be true. To fill up the pores of a sandstone, already partly cemented by silica, by means of carbonate, can do it no harm, and may very likely increase its power of resistance, especially with regard to frost. Thus if we compare the Liver rock of New Braidbar Quarry, which has abundant carbonates, with the more porous Moor rock of the same quarry, in which carbonates are almost absent (Analyses I. and II. *below*), the advantage lies with the former. If, on the other hand, two sandstones be compared—the carbonate cement in the one being replaced by an equal quantity of silica in the other, so that both are equally porous—there can be no doubt that the more siliceous stone will weather the better of the two.

The question of the respective amount of weathering caused by the carbon dioxide and the sulphur dioxide of a city atmophere is discussed in a paper communicated to the Glasgow Philosophical Society in November 1904 by Mr. Samuel Smith.[1] The auther points out that the proportion of carbon dioxide in the Glasgow atmosphere is only about 50 per cent. greater than in places on the sea-coast where it is at a minimum. On the other hand, the proportion of sulphur dioxide in city atmospheres is enormously greater than in the country, and is higher in Glasgow than in Manchester or Liverpool. It seems therefore as if the sulphur dioxide might be at least to some extent the cause of the decay, while the slight increase in the carbon dioxide is obviously insufficient to produce any large part of a weathering so many times greater in Glasgow than in country districts.

The chief supply of building sand in the Glasgow district is obtained from the sheet of glacial sand and gravel which extends along the Kelvin valley from Torrance as far at Kilsyth, and has been worked in numerous sandpits. These are all close to the Kelvin valley railway, which has probably played a great part in bringing these deposits into use.

In conclusion, thanks are due to several firms of builders and quarry-masters in the neighbourhood of Glasgow for information supplied. The list of buildings which follows is taken from reliable sources, but it is unlikely that in a compilation of this kind all errors have been avoided.

ANALYSES OF FOUR BUILDING-STONES FROM THE GLASGOW DISTRICT.

	I.	II.	III.	IV.
SiO_2	81·86	94·22	90·05	90·50
Al_2O_3	1·21	0·44	4·17	0·70
Oxide of Iron	2·59	1·83	1·28	0·92
$CaCo_3$	8·94	0·19	1·65	3·10
$MgCO_3$	4·76	0·19	2·12	2·72
Combined H_2O	0·48	1·30	0·73	1·38
H_2O at 212° F.	0·04	0·80	—	0·70
	99·88	98·97	100·00	100·02
Sp. Gr.	2·291	2·152	—	2·424
Absorption of water per cent.	4·1	6·2	6·2	5·2

I. Giffnock Liver Rock from New Braidbar Quarry. Analyst, Dr. Wm. Wallace; communicated by Messrs. Baird & Stevenson.

II. 'Grey Rock above Liver Rock,'[2] New Braidbar Quarry. Analyst, Dr. Wm. Wallace; communicated by Messrs. Baird & Stevenson.

III. Sandstone from Huntershill Quarry, Bishopbriggs. Analyst, Messrs. R. R. Tatlock & Thomson; communicated by Messrs. Thomas Gibb & Sons.

IV. Sandstone from Bredisholm Quarry. Analyst, Dr. John Clark; communicated by Messrs. Purdie & Murray Ltd.

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[1] 'Decay of Stones in Buildings: the Cause and Prevention,' *Proc. Phil. Soc. Glasg.*, vol. xxxvi., 1905, p. 103.

[2] Probably a part of the 'Moor Rock.'

LIST OF STONES USED IN BUILDINGS IN GLASGOW.

Building.	Source.
Municipal Buildings, Clydebank	Huntershill, Lanarkshire.
Glasgow University	Huntershill, and Giffnock, Renfrewshire, extension partly Plean, Stirlingshire.
Scottish Wholesale Co-operative Society's Building, Morrison Street	Giffnock.
Head Office, Glasgow Savings Bank, Ingram Street	Giffnock.
Glasgow Academy	Giffnock.
Central Railway Station, part facing Union Street	Giffnock.
Post Office, George Square—	
East side	Giffnock.
West side	Dunmore, Stirlingshire.
Ingram Street portion	Hermand, Linlithgowshire.
Bothwell Street, Cambuslang	Eastfield, Lanarkshire.
Silverbank Street, Cambuslang	Eastfield.
South side of Calderwood Terrace, Rutherglen	Eastfield.
St. Joseph's Roman Catholic School, Tollcross	Bredisholm, Lanarkshire.
United Presbyterian Church, Blairhill	Bredisholm.
Established Church, Yoker	Bredisholm.
Ardgowan Terrace, Sauchiehall Street	Wemyss Bay, Renfrewshire.
Partick Bridge	Wemyss Bay.
British Linen Bank, Queen Street. Top storey	Grange, Fife.
Inland Revenue Office, George Street	Partly Hermand, Linlithgowshire, partly Overwood, Lanarkshire.
Royal Exchange and Bank, prior to 1839	Humbie, Linlithgowshire.
Town Hall, Kirkintilloch	Dullatur, Stirlingshire.
Woodilee Asylum, Lenzie (in part)	Dullatur.
Board School, Bishopbriggs, 1908	Dullatur.
Pearce Institute, Govan Cross	In part Dullatur, in part Blackpasture, Northumberland, in part Woodburn, Northumberland.
National Bank, Trongate	Plean, Stirlingshire.
National Bank, St. Enoch Square	Lower part Plean, upper Blackpasture, Northumberland.
Edinburgh Life Assurance Office, St. Vincent Street	Dunmore, Stirlingshire.
Bank of Scotland, St Vincent Place	Dunmore.
Merchants' House, West George Street	Dunmore.
Established Church, Main Street, Rutherglen	Dunmore
Sanitary Chambers, Montrose Street	Overwood.
Stock Exchange, Buchanan Street	Overwood.
Glasgow Herald Office, Buchanan Street	Overwood.
Clydesdale Bank, St. Vincent Place	Overwood.
St. Andrew's Halls, Berkeley Street	Overwood.
Mann, Byars & Co.'s building, Glassford Street	Overwood.
Western Infirmary	Auchinlea, Lanarkshire; additions, Huntershill.
Kelvingrove Art Galleries	Locharbriggs, Dumfriesshire.
Hunter, Barr & Co.'s building, Queen Street	Locharbriggs.
Liberal Club, Buchanan Street	Locharbriggs.
Conservative Club, Bothwell Street	Locharbriggs.
Castle Chambers, Renfield Street	Locharbriggs.
Norwich Union Chambers, St. Vincent Street	Locharbriggs.
West of Scotland Technical College	Locharbriggs, Closeburn, Dumfriesshire, and Cove, Dumfriesshire.
Wm. M'Geoch & Co.'s building, West Campbell Street	Cove.
Ibrox Public School, Hinshelwood Drive, Ibrox	Corncockle, Dumfriesshire.

Building.	Source.
Allan Line Buildings, Bothwell Street	Gatelawbridge, Dumfriesshire.
Sir John Neilson Cuthbertson School, Coplaw Street	Gatelawbridge.
Citizen Buildings, St. Vincent Place, 1886	Ballochmyle, Ayrshire.
Sun Buildings, Renfield Street	Ballochmyle.
Hyndland Church, Hyndland Road, 1885	Ballochmyle.
Barony Church, Castle Street, 1888	Ballochmyle.
Royal Hospital for Sick Children, Scott Street, Garnethill, 1887	Ballochmyle.
C.U. Church, Meadowpark Street, Dennistoun, 1888	Ballochmyle.
Springburn Established Church, Hill Street, 1889	Ballochmyle.
Established Church, Gower St., Bellahouston	Barskimming, Ayrshire.
Masonic Hall, Ayr Street, Springburn	Barskimming.
London Road School	Corrie, Arran.
Scottish Provident Institution Buildings, St. Vincent Street, 1907	Blackpasture, Northumberland.
Mitchell Library, North Street	Blackpasture.
Engineers' Institution, Elmbank Crescent	Blackpasture.
Office of Nobel's Explosives Co. Ltd., West George Street	Blackpasture.
Nurses' Home, Royal Infirmary	Blackpasture.
Post Office, Waterloo Street	Mainly Blackpasture, but partly Prudham, Northumberland.
Office of Northern Assurance Co. Ltd., St. Vincent Street, 1909	Portland Oolite.
Pedestal of Duke of Wellington's Statue, Royal Exchange	Cairngall Granite, Aberdeenshire.

E. M. A.

4. Water Supply.

The chief source of the water supplied to the area included under the Glasgow Corporation Waterworks Act is Loch Katrine, distant thirty-four miles from Glasgow.

The drainage area tapped for this supply measures 26,295 acres in extent, and is entirely occupied by the metamorphic rocks of the Highlands. The water is conveyed from Loch Katrine to the service reservoirs at Milngavie, Mugdock and Craigmaddie, by two aqueducts, which together are capable of discharging 110 million gallons per day. From the service reservoirs the water is at present conveyed to the city by six lines of 36-inch main pipes, to which two additional lines are about to be added. The Loch Katrine water requires no filtration, and is merely strained through fine wire gauze netting.

The Gorbals reservoirs, eight miles south-west of the city, afford another source of supply. The water is drawn from the Brockburn, a tributary of the White Cart. The drainage area is 2560 acres, consisting entirely of volcanic rocks. The amount of water distributed is from 4½ to 5 million gallons per day, besides 1,450,000 gallons per day of compensation water. The Gorbals water is not so pure as that of Loch Katrine, and is filtered through Arran sand and gravel.

The area at present supplied by the Corporation Waterworks measures about twelve miles from east to west, and sixteen miles from north to south. It includes the burghs, towns, and villages of Rutherglen, Cathcart, Pollokshaws, Thornliebank, Nitshill, Barrhead, Cardonald, Renfrew, Govan, Partick, Yoker, Scotstoun, Bearsden, Milngavie, Strathblane, Bishopbriggs, Auchenairn, Millerston, Mount Vernon, Shettleston, Tollcross and Carmyle.

At the Westhorn River Supply Works, two and a half miles above Glasgow Bridge, an average amount of about 2¼ million gallons of water per day is pumped from the Clyde for the use of mills and manufactories along the banks of the river.[1]

Wells.—A good supply of water is obtained from the deep bore at the Wellpark Brewery, Duke Street. The bore passes through the Millstone Grit into the Carboniferous Limestone to a depth of 1048 ft. from the surface. The main spring was tapped at 480 ft., and the water rises to a point 60 ft. from the surface. The water from this bore is mixed for brewing purposes with the Loch Katrine water, and, as it contains sulphates, supplies an element in which the latter is lacking.

A more recent bore, situated 10 yds. west of south from the above, went down to 1026 ft. The water from this bore was found to be highly charged with alum and salt.

Water is raised from old coal wastes, probably those of the Ell Seam, in the eastern part of the city for use in dyeworks and other manufactories. The long time elapsed since this seam was wrought ensures a purity in the water sufficient for these purposes. L. W. H.

Water from the eastern part of the Campsie volcanic plateau is collected in the Birken Burn reservoir, at the head of the Garrel Burn, and in two smaller reservoirs on the slopes of the Brown Hill. The former supples the eastern district of Stirlingshire, the latter the town of Kirkintilloch.

There are also several small reservoirs in the volcanic area of the Cathkin Hills ; from two of these, Turnlaw and Cairnmuir, Cambuslang derives its water supply. The ashy beds between the lava-flows on the northern front of the Cathkins are frequently water-bearing, and supply good potable water for local use. E. M. A.

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[1] The statements and figures given above have been kindly checked and brought up to date by Mr. J. R. Sutherland, Engineer's Office, Glasgow Corporation Water Works.

APPENDIX I.

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LIST OF WORKS RELATING TO THE GEOLOGY OF THE GLASGOW DISTRICT.[1]

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[1] Includes a certain number of papers dealing with the geology of areas lying just outside the limits of the Glasgow District Sheet, *e.g.* Airdrie, East Kilbride, Paisley, etc.

Much useful information will also be found in the shorter notices and accounts of excursions printed in the Proceedings of the Glasgow Geological (*vide Transactions*), and Natural History Societies.

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APPENDIX II.

GLOSSARY OF MINING TERMS, ETC., USED.

Blackband Ironstone.—Consists of carbonate of iron laminated with coal, and differs from a clayband ironstone in usually containing sufficient coal to calcine the ore without admixture of additional fuel.

Blaes.—Mudstone, more or less laminated, or shale (in the geological sense) not containing much bituminous or carbonaceous matter, but generally sufficient to give a dark-blue (" blae ") colour to the rock.

Blind coal.—Coal which has been partly carbonised, and in general rendered valueless by its proximity to an igneous intrusion.

Blind bore, or *pit.*—A bore or shaft which does not reach the surface, *i.e.* one drilled upwards or downwards from an underground position.

Brushing.—Strata above or below a worked seam, taken out in making the roads.

Calmy limestone.—Argillaceous limestone.

Cannel (*i.e.* candle) *coal.*—Long-flaming coal, yielding gas of high illuminating power on distillation, of lustreless appearance, and with a conchoidal fracture.

Cementstone (often *cement* for short).—An impure earthy or argillaceous limestone, forming a natural hydraulic cement of diverse quality when burnt.

Cross-cut, cross-cut mine.—A drift or roadway driven from one seam to another.

Craw (or *crow*) coal.—Inferior coal, usually a thin seam.

Daugh.—Soft, often coaly, fireclay, especially when found above, below, or as a parting in, a coal seam.

Day-level.—A level driven from the surface.

Fakes.—Thin-bedded argillaceous sandstone or sandy mudstone ; passing through *faky sandstone* into sandstone, and through *faky blaes* into blaes.

Float.—A sill or sheet of igneous rock, either horizontal or inclined, but more or less in accordance with the bedding.

Gas coal.—(1) Cannel coal (*q.v.*) ; or (2) coal used for gas-making purposes.

Gaw.—A narrow dyke of igneous rock.

Kingle or *kennel.*—Very hard rock, especially sandstone cemented by silica or carbonates.

Metals.—Strata.

Mine.—A drift or roadway from the surface (Day-level) ; or a drift from underground workings which does not follow the seam but cuts across the strata (cross-cut, stone mine) ; *not* a shaft.

Mussels.—Typically freshwater or estuarine lamellibranchs belonging to the genera—*Carbonicola, Anthracomya, Naiadites.*

Musselband.—Blaes or ironstone containing numerous " mussels."

Opencast.—A surface working or quarry.

Parrot Coal.—A term for cannel (*q.v.*) or gas coal ; the name is probably derived from the chattering noise made by this kind of coal in burning. Also as an adjective *parroty, e.g.,* parroty blaes.

Post.—A solid, generally rather thick bed, especially of sandstone or limestone.

Pugs.—A band of hard splinty coal in a coal seam.

Rock.—Sandstone, unless otherwise described.

Rough Coal.—A name often used for ordinary coal to distinguish it from cannel or splint.

Shales.—See under *Blaes.* Both terms have been used in this memoir for more or less laminated mudstones. In Scottish Mining parlance *shale* generally denotes oil-shale, *e.g.* p. 112.

Slatyband.—A fissile ironstone, composed of alternating laminæ of clayband and of blackband.

Slicken-sided.—Used to describe the smooth, polished surfaces produced by movements in rocks.

Splint coal.—Hard coal, with a dull lustre and uneven fracture, which does not cake or break up easily in a furnace.

Stone mine.—A mine driven in barren strata.

Strong.—Hard ; *e.g. strong blaes,* hard fissile, but not brittle, blaes.

Want.—A barren area met with in a coal seam.

Waste.—Old workings.

Whin, whinstone.—Hard igneous rock ; occasionally the term is used for other hard material.

Wild coal, wild parrot.—Inferior coal or inferior gas coal respectively.

INDEX.

A

Acre, 61.
Ailsa Craig, setts from, 252.
Airdrie, 113.
—— Blackband Ironstone, 130.
Airdriehead, Cumbernauld, 154, 194.
Akerite, 183, 184.
Albite-trachytes, 178, 181.
Albitization, 167-168, 181.
Aldessan Burn, 138.
Alexandra Parade, sections at, 95, 130, 160.
—— Park, 236, 255.
Allanfauld, 63.
Allport, S., 164, 165, 166, 169, 172, 173, 176.
Alluvium, freshwater, 2, 230, 233-234.
Alston, W. M., 217, 242.
Alton Basin, 78.
Alum Shale, 32, 34, 36, 37, 39, 40-41, 44, 45.
Alvain Burn, 156.
Analcite, in basalt, 178, 180; in essexite, 170, 171; in phonolite, 184; in teschenite, 164, 165, 172-173; in theralite, 174.
Analyses of: akerite, 183; Ballagan cementstones, 12, 245; basalts, 177, 182; bekinkinites, 174; building stones, 264; coals, 64, 65; essexites, 170, 177; felsite, 185; fireclays, 89-90; ironstones, 50, 65, 112; laurvikite, 183; limestones and cements, 243-250; mugearites, 182; nepheline-basalt, 174, 182; nepheline-teschenite, 170; phonolite, 184; picrite, 174; quartz-dolerite, 188; trachyandesite, 183; trachyte, 183.
Anderson, E. M., 72.
—— W. C., 55.
Annanlea Sandstone, 258.
Antermony Loch, 157.
Anthracite, 65, 66, 67.
Arbroath flags, paving stones of, 252.
Arden Basin, 1, 3, 32, 49, 68, 69, 78, 191, 198, 202-204, 237, 246.
—— Coals, 67, 70, 72. *See also under* Hirst.
—— Limestone, 32, 67, 70, 72, 74, 203, 243, 246; analysis of, 245; classification of, 249, 250. *See also under* Calmy.
Area and Physical features, 1. *See also* Chapter XII.
Arkhaven, 149.
Arkleston, sections at, 19, 20, 25, 36, 37, 162.
Armadale Coals, 86, 93, 95, 101.
Armstrong, J., 71, 74, 123.
Arnbrae-Nethercroy Fault, 196, 208-209.
Arran, 135; building-stone from, 257; sand and gravel from, 266.
Ashfield, 158, 159, 210.
—— Pits, 58, 59.
Auchenairn, 266.
Auchengeich Colliery, 55, 61.
Auchenreoch Glen, 120.
Auchentoshan, 27.
Auchinback, 34, 35; sections at, 36, 67, 69, 244.
—— Coal, 70.
Auchinbee, 35, 46, 154.
Auchineden Hill, 139, 178.
Auchinlea, Cleland, building-stone from, 257, 265.
Auchinloch, 159.
Auchinreoch, 153, 154.
—— Colliery, 63, 64.
Auchinstarry, 157, 194; analysis of dolerite from, 188.
Auchinvole, 64, 196,
Augite-monchiquites, 178.
Auldhouse Burn, section in, 71-72.
Avenuehead, moulding sand quarry at, 74, 255, 260.
Avon, River, 88.
Ayrshire, 15, 38, 56, 74; building stones from, 257, 258; igneous rocks of, 135, 151, 152.

B

Badenheath, 154.
Bailey, E. B., 140, 150, 167, 187, 228, 240.
Baillieston district, 3, 210, 211, 222, 256; Coal Measures of, *see* 108-118; Millstone Grit of, 85; structure of, 206; west-north-west dykes of, 149, 152, 163-164, 213.
Baird and Stevenson, Messrs, 264.
Baldernock, 40, 41.
—— Limestone, 17, 18, 19, 23, 24, 25, 27, 31, 127, 159.
—— Mill, 27, 159.
Baldow Glen, 23, 24, 26, 41, 42, 43,
Balfron, 230,

Balglass, 144. *See also under* Corrie.
—— Burn Beds, 23.
Balgray, 55, 58.
—— Reservoir, 69, 212, 249.
Balgrochan, 24, 25, 41.
—— Beds, 23, 24-26, 27, 30.
Baljaffray, 39.
Ballagan (or Cementstone *q.v.*) Group, 2, 8, 10, 11-13, 145, 238.
—— Burn, 11, 240.
—— Cementstones, 12; analyses of, 12, 245.
—— Spout, 11, 120, 244.
—— Tops, 144, 145.
Ballewan, 156.
Ballochmyle Quarry, building-stone from, 258, 266.
Balmalloch, 63, 194, 196, 208.
Balmoral Coal, 86, 91, 92, 93, 95, 96, 100, 101, 108, 109-110.
—— Index, 110.
Balmore, 60, 192.
—— Haughs, 75, 92, 234.
Balquharrage Beds, 28, 73.
BALSILLIE, D., 151.
Bank Coal, 61.
Bankhead, Rutherglen, 98.
——, Scotstounhill, 162, 163.
Bannock Burn, 30, 31.
Bannockburn Main Coal, 62.
Banton, 64, 194.
—— Blackband, 56, 62, 63, 64, 65, 194.
—— Claybands, 56, 64.
Barbeth, 154.
Bardowie, 41.
—— Loch, 75.
Bargeddie, 94, 108, 116, 117, 118.
Barhill, 42.
Barnellan, 208, 209.
Barnhill, 216.
Barniemore, 145, 179.
Barr Hill, 64, 154, 155.
Barrachnie, 114, 115.
Barraston, 24, 35, 40, 42, 43.
Barren Red Measures, 2, 3, 10, 94, 107-108, 131, 191, 206, 210, 211, 216, 226, 256, 257.
Barrhead district, 1, 3, 19, 20, 21, 36, 38, 48, 51, 52, 53, 67, 68, 69, 72, 202, 203, 212, 244, 246, 266.
—— Grit, 68-69, 70, 203, 212, 237, 253.
BARROW, G., 16, 166, 180.
BARROWMAN, J., 98, 115.
Barshaw Theralite, or Bekinkinite, 162-163, 165, 168, 174-175; analysis of, 174.
Barskimming Quarry, building-stone stone from, 258, 266.
Barwood Colliery, 66.
Basalts, 2, 135-149 *passim*; petrology and analyses of, 175-185.
Basanites, 172.
Basket Shell-bed, 15.
Batchie Blackband, 54, 59, 60, 61.
Bathgate Hills, 149, 150, 178.
Baught Glen, 41, 42, 43.
Bearsden, 34, 35, 210, 225, 226, 238, 266.
Bearsden pre-glacial valley, 215, 216, 217, 218, 219. *See also under* Kelvin.
Bedlay, 57, 74, 159, 246.
Bekinkinite of Barshaw. *See under* Barshaw.
Bekinkinites, 175, 181; analyses of, 174.
BELL, D., 219, 222.
"Bellerophon Limestone," 44, 126.
Bellgrove, 83, 95.
Bellshill, 257.
Belvidere clay-pit, 232.
Bencloich Mains, 24, 40, 42.
—— mill dam, 24
BENNIE, J., 218, 223, 232.
Berryhill Farm, 177.
Bin Burn, 228.
Binny Sandstone, 257.
Birdston, 153, 154, 194.
Birken Burn Reservoir, 267.
Bishop Loch, 91, 109, 234, 237.
Bishopbriggs, 53, 55, 57, 58, 59, 61, 74, 158, 159, 191, 209, 222, 237, 251, 266; section of Upper Limestone Group at, 68; sections at, 75-77.
—— Sandstone, 61, 67, 72-73, 76, 77, 78, 253-254, 257, 262; analysis of, 264.
Bishopton, 231.
Black Cart, River, 215; pre-glacial valley of, 215, 216, 217, 219.
—— Loch, 139, 176, 189.
—— Metals, 32, 46, 49, 51, 54, 56-57, 58, 62, 63, 64, 124, 154.
Blackband Coal, 96, 97, 98, 100, 102, 108, 113-114, 162.
—— Ironstone. *See especially under* Airdrie, Banton, Batchie, Blairdardie, Drumchapel, Fourteen-inch, Garscadden, Goodockhill, Haugh, Ibrox, Jordanhill, Main, Neilston, Palacecraig, Possil, Twechar.
Blackbyre, 19, 21, 25.
—— Limestone, 17, 18, 19-21, 24, 25, 26, 27, 30.
Blackhall, 19, 21, 36, 37, 38, 212.
—— Limestone, 24, 26, 28, 34, 35, 37-38, 40, 42, 43, 44, 45, 46, 127, 153, 162, 163, 201.
Blackhill, Riddrie, 158, 161.
—— Colliery, Maryhill, 58, 59, 60, 95.
Blackpasture Quarry, Northumberland, building-stone from, 257, 265, 266.
Blairdardie, 58, 59, 61, 201; clay-pits at, 218-219.
—— Blackband, 59, 61.
Blairskaith Muir, 24.
Blairtummock, 162.
BLAKE, G. S., 187, 188.
Blane Valley, 140, 144, 149, 238, 241. *See also* Strathblane.
—— Water, 235.
Blanefield, 176, 207.
Blantyre, 101, 102, 106.
—— Colliery, 103, 104, 105.
Blantyreferme Colliery, 104, 105, 106.
Blawarthill, 163, 225.
Blochairn, 80, 83, 84, 198.

Blochairn Quarry, sandstone of, 85, 255, 259, 260, 261 ; microslides, 263.
Blythswood Fault, 212.
Boards, 139, 140, 176.
Boghall Coal, 53.
Bogleshole Pit, 101, 103, 105.
Bogton House, 255.
Bonawe Quarry, granite from, 252.
Bothwell Castle, 107, 237.
—— district, 1, 94, 99-108, 164, 217.
—— Park Quarries, 257.
Bothwellhaugh, 164.
Boulder-clay, 214, 222 223-227 ; intercalated with sand, and gravel, 218, 219, 220, 223, 225, 226 ; shelly, 231.
Boulders, erratic, 220-222, 223, 224, 225, 226.
Bowling, 216.
Bowlingite, 141.
Boyd's Burn, 41.
Boyle, R., 165, 257.
Brady, H. B., 122.
Braehead, Baillieston, 265.
——, Kilsyth, 63.
——, Renfrew, 201.
Braehouse, 63, 194, 196.
Braes of Campsie, 22. *See also* North *and* South.
—— —— Yetts, 78.
Braidbar Quarries, 254, 255.
Braidfield, 55.
Brand, M., 65.
Bredisholm, 102, 110, 111, 113, 115, 116, 117, 163, 164, 233.
—— Quarry, 211, 213, 256, 262, 265 ; analysis of sandstone from, 264.
Brick-clays, 228, 231, 232.
Bridge of Weir, 20, 21, 25, 31, 35, 37, 38, 39.
Bridgend Farm, 74, 87,
Brock Burn, 266.
Brögger, W. C., 165, 167, 170, 171, 177.
Broomhouse, 101, 102, 110, 206 ; sands and gravels at, 226, 227.
Brown Hill, 208, 267.
Brownside, 21.
Budhill Quarry, Shettleston, 256.
Building stones, 252-266 ; analyses of, 264 ; characters and weathering qualities of, 258-264 ; microslides of, 263 ; sources of supply outside Glasgow district, 257-258 ; used in Glasgow, 265-266.
Burdiehouse Limestone, 14.
Burnbank, 80, 83, 95, 160.
Burnel Rannie, 24, 25, 41.
Burnhead, 29, 45, 46, 62, 196.
Burnlip bore, 82, 83.
Burnside, 211, 212.
Burntbroom, 110, 115.
Busby, 42, 69, 244, 249, 250.
Byshot, 189.

C

Cadder district, 48, 53, 55, 60, 61, 65, 73, 153, 223, 233 ; general section of, 54 ; quartz-dolerite dykes of, 157-158.
Cadder Fault, 157, 209.
—— Ironstones, 46, 54, 59, 60-61.
—— Main Coal, 54, 59, 60, 61 ; analysis of, 64.
Caddercuilt, 60.
Cadell, H. M., 235.
Cairnbog, 44, 45, 46, 63, 64 ; fault at, 45.
Cairnmuir Reservoir, 267.
Caithness Flags, paving stones of, 252.
Calcareous Coals, 103, 104.
Calciferous Sandstone Series, 2, 3, 8, 10-13, 14-31, 34, 191, 192, 201, 206, 211, 216 ; building-stones from, 253, 257 ; palæontology of, 119, 120-122, 125, 132 ; upper limit of, 14-15 ; vertical sections of, 33.
—— —— ——, volcanic rocks of, 2, 3, 13-14, 135-149, 191, 192, 202, 203, 206, 211 ; petrology, 175-185 ; zeolites in, 188-190.
Calder, River. *See under* North, Rotten, South.
Calderbank, Airdrie district, 130.
——, Baillieston, 96, 110, 115, 163.
Calderwood Cement, 39, 127, 243, 246.
Caledonia Fireclay Pit, Paisley, 18, 21.
Caledonian Brick Works, Polmadie, 232.
California Claybands, 46, 51, 54, 56, 57.
Calmy Limestone, 32, 67, 70, 73-74, 75, 77, 78, 79, 125, 126, 153, 159, 192, 194, 196, 198, 203, 210, 243, 244, 255, 257 ; analysis of, 245 ; classification of, 249, 250.
Cambuslang, 3, 94, 116, 211, 217, 218, 222, 267 ; building stones from, 256.
—— Marble, 97, 98, 99, 105, 115, 129.
—— Uddingston and Bothwell district, 95, 99-108.
Campbell, R., 152.
Campsie Alum Works, 27, 192.
—— Claybands, 34, 42, 43, 45.
—— district, Calciferous Sandstone Series in, 11-13, 16, 17, 19, 20, 22-28, 29, 30 ; Lower Limestone Group in, 35, 37, 39, 40-44, 45, 123, 127 ; structure of, 192 ; Upper Old Red of, 7.
—— Dyke, 156.
—— Fault, 3, 11, 13, 22, 29, 135, 137, 139, 152, 191, 192, 196, 207-208, 238.
—— Fells, 1, 2, 3, 7, 8, 11 ; drainage system of, 237, 238-241 ; glacial phenomena of, 220, 223, 228-230 ; peat on, 234 ; road-metal from, 250 ; structure of, 191, 192 ; volcanic rocks of, 13-14, 135, 136, 137-139, 142-149, 166-167, 175-185 ; water-supply from, 267.
—— Glen, 2, 11, 13, 137, 138-139, 156, 228, 240, 241.
—— Main Limestone (and Coal), 28, 29, 34, 40-41, 44. *See also under* Hurlet Limestone.
Capelrig, 191.
Car Craig, teschenite of, 165, 172,
Carbeth, 140, 167, 190.

Carboniferous Formation, 2, 10-118; conditions of deposition of, 131-132; life zones in, 132-134; palæontology of, 119-131.
—— Limestone Series, described, 32-79; building stones from, 252, 253-255, 257, 260-266; limestones from, 243-250; palæontology of, 120, 121, 122-127, *and see also* 131-134; subdivisions of, 2, 3, 32; and additional references *passim*.
Cardonald, 39, 50, 51, 266.
Cardowan, 111, 113, 162, 198.
—— House, 75.
—— Moss, 234.
Carluke, 30, 42, 56.
Carmichael, J., 36.
Carmunnock, 15, 202, 250.
Carmyle, 1, 101, 102, 104, 105, 211, 217, 266.
Carnarvon, granite setts from, 252.
Carron Ironworks, 45.
—— River, 228, 235, 236, 239, 240, 241.
Carruthers, R. G., 14, 17, 43, 72, 133, 152, 214, 233.
Castlecary, 83, 196.
—— Limestone, 32, 67, 74, 75, 79, 80, 81, 82, 87, 92, 133.
Castlehead Coals, 18, 22.
Castlehill, Campsie, 43.
——, Kilpatrick, 39.
Castleton, 211, 212.
Cathcart, 3, 67, 69, 266.
—— Hills, 135.
—— teschenites, 149, 160, 165, 168, 171-172, 203; analysis of, 170.
Cathkin Hills, 1, 3, 136, 137, 211; lavas and tuffs of, 140-142, 167, 176, 178; road-metal from, 250; structure of, 202; water-supply from, 267.
Cathkinite, 141.
Cathrein, A., 168.
Cement, Cementstone, 283. *See under* Calderwood, Huntershill, Roman.
Cementation Index, 248.
Cements and Limestones, *see* 243-250.
Cementstone Group, 2, 10, 11-13, 14, 137, 191, 208, 241, 253; palæontology of, 119, 120. *See also* Ballagan.
Cementstones of Liddisdale, 14, 15, 22.
Chapelgreen Coals, 67, 73, 78, 196.
Chapelhall, 130.
Cherry Coal, 53.
Chryston district, 48, 57, 61-62, 68, 73, 74, 125, 222, 237, 255; dykes of, 157; structure of, 198.
Clachertyfarlie Knowes, 148.
Clachie Burn, 147.
Claddens Dyke, 74, 158, 237; quarry in, 158, 251.
Clark, J., 264.
Clarkston, 203.
Clayband Ironstone. *See especially under* Banton, California, Campsie, Garibaldi, Househill, Johnstone.
Cleddans, 35, 39, 40.
Clefted Coal, 109.
Cleuch, 203, 212, 244, 249.
Cloberhill, 54, 59.
—— Blackband, 59.
Clochcore, 27, 28.
Closeburn Quarry, Dumfries, building-stone from, 257, 265.
Clough, C. T., 94, 113, 130, 149, 151, 152.
Cloven Coal, 59, 63, 65, 66.
Clyde, River, 1, 107, 163, 201, 211, 223, 225, 237, 267; artificial deepening of, 241-242; early history of, 235; post-glacial terraces of, 230-233, 236; pre-glacial valley of, 214-220, 236, 237.
—— Iron Works Colliery, 101, 102, 103, 105.
—— Trust, 201, 217.
—— Volcanic Plateau, 10, *and see under* Volcanic Rocks.
Clydebank, 198, 215, 216, 217.
Clydeside, 101.
Coal and Ironstone Group, 34. *See under* Limestone Coal Group.
Coal Measures, base of, 81, 85, 86, 91, 92, 93, 98, 100, 109; marine bands in, 95, 130, 131. *See also under* Barren Red Measures *and* Productive Coal Measures.
Coatbridge district, 1, 3, 86, 112, 117, 218; Balmoral Coal of, 101, 109; boulder-clay of, 226-227, 237; striæ in, 222.
Cobbinshaw, 14, 244; analysis of limestone from, 245.
Cochno Burn, 28.
Coking Coal, of Ashfield, 59.
—— —— of Kilsyth. *See* Kilsyth.
—— properties, 64, 65, 67.
Colinburn Coal, 86, 93.
Coltmuir, 159.
Coltpark Quarries, 76, 254.
Colville and Sons, Ltd., Messrs D., 50.
Colzium House, 209.
Comedie, 112, 113, 210.
—— Fault, 55, 80, 198, 206, 210.
—— Pits, 112, 113, 114.
Conacher, H. R. J., 17, 21, 23, 24, 25, 26, 27, 30, 37, 40, 41, 42, 43, 44.
Condorrat, 154.
Corkerhill, 34, 36; Pollok Pit at, 37, 39, 50, 246.
Corncockle Quarry, Dumfries, sandstone from, 252, 257, 265.
Cornstones, 7, 8, 9.
Corrennie Quarry, Aberdeen, granite from, 258.
Corrie (and Corrie Burn), 3, 13, 17, 20, 28-31, 34, 35, 43, 44-46, 126, 244; analyses of limestones from, 245.
Corrie, Arran, building-stone from, 257, 258, 266.
Corrie of Balglass, 13, 120, 137, 146, 228, 240, 241.
Corrom, 230, 240.
Cort-ma-Law, 208.
Cove Quarries, Dumfries, building-stone from, 258, 265.
Cowal, Tertiary dykes of, 213.

Cowdenhill, 201.
Cowglen, 49, 52, 53, 69, 253; general section at, 49.
—— Limestone, 67. *See* Index.
Cowlairs, 72, 237.
—— Sandstone, 61, 76, 77.
Craig, R., 37, 201.
Craigallian, 140.
—— Loch, 140, 190.
Craigannet Hill, 137.
Craigash Quarry, 253, 262.
Craigbock, 7.
Craigend Muir, 22, 28.
—— Quarry, 250.
Craigenglen Beds, 23, 25, 26, 27, 30.
—— Burn, 26, 42.
—— Cottage, 26.
Craighead Colliery, 100.
Craiglockhart basalts, 153, 175-176, 177; in Campsie Hills, 138, 176; in Kilpatrick Hills, 139, 140, 189.
Craigmaddie Muir, 22, 28, 29, 40, 41, 157.
—— —— Sandstones, 8, 16, 17, 23, 27, 28, 192, 208, 253; striæ on, 220.
—— Reservoir, 28, 160, 266.
Craignurite, 187.
Craigroot Quarry, 251, 254.
Craigton, 140, 253.
—— House, 233.
Crampton, C. B., 23, 30, 44, 149, 150.
Cranhill, 113.
—— Quarry, 250.
Crawfordjohn, essexite of, 149, 168, 169, 170, 171.
Crofthead Coal, 93.
—— Slatyband Ironstone, 81, 86, 93, 95.
Croll, J., 218, 219, 223.
Crookston Castle, 212.
—— Fault, 36, 212.
Crosshill, Rutherglen, 98.
Crosskey, H. W., and D. Robertson, 214, 231.
Crossmyloof, 35, 36, 50, 211.
Crosstobs, 21.
Crowhill Quarries, 76.
Croy, 153, 154, 157, 209.
—— and Milton (or Cumbernauld) Dyke, 157.
—— Fault, 154, 157, 196, 209.
"Crush-conglomerate," 144.
Cullalo, Fife, building-stone from, 257.
Culloch Slap, 41.
Cumbernauld, 89, 153, 154, 194, 196.
—— Dyke, 195. *See* Croy and Milton.

D.

Dalbeth, brick-clays at, 232.
Dalmarnock, 218.
Dalmeny basalts, 178; in Cathkin Hills, 136, 140, 141, 178.
Dalmuir, 22.
Dalshannan, 154.
Damm, A., 177.
Darnley Coal, 53.
Darnley Fireclay, 70, 125.
—— Quarries, 67, 70, 244, 246; analysis of limestone from, 245; classification of limestone from, 249, 250.
"David Dale's Dyke," 211.
Davidson, T., 29, 84, 124.
Davieland, 70, 203.
Davis, W. M., 240.
Davy Coal, 57. 59, 61.
Dawsholm, 72, 73.
Day, T. C., 152.
Deaconsbank, 72.
Deanfield, 201.
Dechmont Colliery, 102, 106.
—— Fault, 3. 96, 100, 191, 202, 203, 206, 211, 212, 213.
—— Hill, 211, 218, 225, 227.
Dennistoun, 160, 236.
Denny, 35, 166.
Devil's Crag Dam, 189, 190.
Dick, A., 183, 260.
Dixon and Co., Ltd., Messrs Wm., 59, 81, 201.
Dolerite dykes and sills. *See under* Olivine-dolerite, quartz-dolerite, teschenite.
Douglas, 15, 94.
—— Muir, 22, 27, 28, 225.
—— Park Colliery, 105.
Dovecotwood, 63.
Dron, R. W., 55, 64, 82, 92, 103.
Drum Mains, 194.
Drumairn, 156.
Drumbreck, 194.
Drumcavel, moulding sand at, 255, 258, 260.
Drumchapel, 55, 56, 58, 59, 61, 72, 201, 231, 233.
—— Blackband, 59, 61.
Drumgray Coals. *See* Lower, Mid, Upper.
Drumlins, 214, 220, 222, 223, 226, 227, 232, 234, 236, 237, 238.
Drumoyne, 50, 51.
Drumpark, 94, 108, 115, 118, 130, 220, 226, 228.
Drumpellier, 112, 116.
Drymen lake deposits, 230.
Dullatur, 153, 154, 157, 209.
—— Dyke, 156-157, 208, 209.
—— Sandstone, 61, 254, 265.
Dumbarton, 120, 235, 236.
Dumbreck, 153, 194.
—— Colliery, 63, 64, 65, 78.
Dumbuck, 241.
Dumfoyn, 142, 144.
Dumfriesshire, 15, 94; building-stones from, 257, 258.
Dumgoyn, 138, 142, 144.
Dunbar, 13, 30.
Duncomb Hill, 177.
Dunglass, 164, 180.
Dungoil, 142, 146, 148, 179, 240.
Dungoyach, 144, 207.
Dunlop and Co., Ltd., Messrs J., 50.
—— R., 130.
Dunmore, 146, 179.
—— Quarry, Plean, 257, 265.

Dunsapie basalts, 175-176, 183, 189; analyses of, quoted, 177; in Cathkin Hills, 140, 141, 142, 148, 250; in Kilpatrick Hills, 139, 140, 189.
Duntocher, 22, 39, 55, 225.
—— Burn, 27.
Duparc, L., 168.
Dykebar Limestone, 17, 18, 22, 27, 121.
—— Marls, 18, 21-22.
Dykes, of volcanic epoch, 147-148; olivine-dolerite, *q.v.*; quartz-dolerite, *q.v.*

E

Earl's Seat, 1, 238.
Earthquake in Glasgow, 210.
East Board, 154, 209.
—— —— dyke, 154, 157.
—— Cowlairs, 61, 72, 75.
—— Kilbowie, 55.
—— Kilbride, 14, 15, 43, 48, 50, 119, 127, 243, 246.
—— Paisley and Hurlet district, 18-22, 35-39.
—— Parkhead Colliery, 105.
Easter Bedcow, 158.
Easterhouse, 101, 111, 115.
Easterton, 78.
Eastfield Colliery, Bishopbriggs, 58.
—— Quarry, Rutherglen, 99, 256, 262, 265.
Eastpark, 57, 58.
—— Quarry, 253.
Eckel, E. C., 248, 249, 250.
Edmondia punctatella, 70, 73, 74, 125-126.
Elderslie, 21.
—— House, 163, 201, 212, 217.
—— Rock, 163, 216.
Ell Coal, 96, 97, 98, 99, 100, 105-106, 108, 115-116, 129, 164, 256, 267.
Ellismuir Colliery, 111, 113, 164, 211.
Endrick, River, 6, 235, 236.
Ennos, F. R., 184, 185.
Erratic boulders. *See* Boulders.
Eskdalemuir, 186.
Essexite (Lennoxtown), 149, 152-153, 165, 168, 169-171, 172, 176, 256; analysis of, 170; erratics of, 220-222.
Essexites, 165, 167, 169, 171, 177, 182; analyses of, 170, 177.
Etheridge, R., Jun., 5, 123.

F

Faifley, 28.
Falconer, J. D., 149, 165, 179, 187, 188.
Farme Colliery, 96, 98.
Fauldhouse district, 86, 93, 95, 101.
Faults, 207-213.
Felsites, 147, 148, 167, 185, 192; analysis of, 185.
Ferguslie Fireclay, 22.
Ferguson, D., 18, 44.
Fernhill, 141.
Ferrets, 43.
Fin Glen, 11, 13, 156, 240.
Finnie's Croft, 24.
Fintry, 1, 3, 181, 230, 238, 240, 241.
—— Phonolite, 148, 167, 168, 184-185.
—— Valley, 230, 240.
Fireclay, *see especially* 22, 70, 80, 83, 85, 86-91, 109; analyses of, 89-90.
Firpark Quarries, 160, 251.
First Ironstone Coal, 49, 52.
Fishescoates Colliery, 98.
Fleming, J., 8.
Flemington Farm, 227.
Flett, [Sir] J. S., 149, 167, 174, 180, 181, 182, 186.
Forge Sandstone, 117.
Formations, Table of, 2.
Forth, River, 235.
"Fossil Forest," Whiteinch, 122, 163.
Fourteen-inch Blackband, 54, 59, 60.
Foxley, 85, 110.
Freetrader Pit, 51.
Furness Quarry, Loch Fyne, setts from, 252.

G

Gain, 87; analysis of fireclay from, 89-90.
Gairloch Hill, 142, 144, 145, 148.
Galliston basalt, 173, 178, 179.
Gallowhill, 17, 19, 20.
Garabal Hill Granite, erratics of, 220, 224, 225.
Gareloch, 235.
Garibaldi Claybands, 46, 49, 51, 54, 56, 62, 63, 64.
—— Coal, 56.
Garmore, 42, 43.
Garngad Road Cement, 84, 85, 255.
—— —— Quarry, 80, 84-85, 255.
—— —— Station, sections near, 75, 80, 83, 95, 127.
Garnkirk Basin, 3, 80, 82; section across 198, 199.
—— district, 32, 57, 61, 73, 75, 83, 86-87, 234, 246; section of Upper Limestone Group in, 68.
—— Fault, 74, 80, 158, 198, 210, 213.
—— Gas Coal, 73.
—— Limestone. *See* Calmy.
Garnqueen, 80, 86, 87.
Garrel Burn, 8, 11, 13, 136, 137, 138.
—— Hill, 138.
Garscadden, 53, 55, 56, 243.
—— Blackbands. *See* Lower, Upper.
—— Subgroup, 32, 46, 50-51, 54-57.
Garscube, 56, 57, 58, 59, 61, 72.
—— House, 210, 237, 254.
Gartcarron Hill, 240.
Gartcloss Colliery, 113, 115, 116.
Gartcosh, 86, 87.
Gartcraig, 86, 96, 109, 110, 111; teschenite at, 161, 162, 236, 251.
Gartferry House, 74.
—— Mains, 158, 210.
Garthamlock, 85, 86, 109, 114.
Gartliston, 86.

Gartloch, 198, 206, 222.
Gartnavel, 56, 57, 58, 61.
Gartness, 6.
Gartocher, 114.
Gartsherrie, 91, 110, 113, 115, 116.
—— bore, 82, 92, 109, 110.
Gartshore, 63, 64, 65, 66, 67, 155, 157.
—— House, 78, 209.
Gartverrie, 83.
Gas Coal, Cardonald, 51.
—— ——. *See under* Knightswood, Shotts, Titwood,
Gatelawbridge, Dumfries, building-stone from, 258, 266.
Gateside, 101, 102, 103, 106.
Gavell, 153, 209, 251.
—— -Croy Faults, 66, 154, 155, 156, 196, 209.
—— House, 194.
Geikie, [Sir] A., 8, 13, 16, 135, 136, 144, 147, 150, 151, 164, 165, 166, 167, 173, 177, 179, 185.
—— J., 219, 230.
Geordie's Coal, 49, 52.
Germiston, 3, 80, 262.
—— Quarry, 85, 256, 259, 260, 262.
Gibb and Sons, Messrs T., 264.
Giffnock, 36, 46, 48, 50, 70-72, 228; section of Upper Limestone Group at, 68.
—— Colliery, 49, 53, 70, 71.
—— Sandstone, 71, 73, 78, 222, 253, 254-255, 262, 264, 265; microslide of, 263.
Gilmore Hill, 57, 224.
Gilslochhill, 60, 61.
Glacial phenomena, 214-230.
Glasgow, *passim.*
Glazert, River, 22, 25, 192, 234.
Glen, D. C., 141, 163.
Glen Fyne, erratics from, 220, 222.
Glenboig, 75, 82, 83, 86-88.
—— Fireclay, 83, 86, 87, 88-89; analyses and physical tests of, 89-90.
Gleniffer Limestones, 18.
Glenwhapple, 26, 42.
Glenwynd, 24, 26, 41.
Glorat, 27, 41.
—— House, 24, 43.
Godwin-Austen, R. A. C., 8.
Goil, Loch, 235.
Golfhill, 236, 251.
Gonachan Burn, 230, 240, 241.
Goodchild, J. G., 8.
Goodockhill Slatyband Ironstone, 86.
Gorbals Reservoirs, 266.
Govan, 36, 50, 52, 201, 211, 212, 217, 266.
—— anticline, 198, 216.
—— Blackband, 49, 51.
—— Colliery, Rutherglen, 80, 81, 82, 98, 99.
Grabham, G. W., 149, 167.
Grange Quarry, Burntisland, building-stone from, 257, 265.
Grangemouth, 218, 236.
Granite: erratics of, 220, 222, 224, 225; for ornamental uses, 258; for setts, 252.
Greenfield, Blantyre, 101, 103.
——, Shettleston, 114, 115, 116, 162.
Greenfoot Quarries, 87, 88.
Greenhead, 35.
Gregory, J. W., 87, 210, 258.
Grossart, W., 95.
Gryfe, River, 25.
Gunn, W., 136, 150

H

"Haggis Rock," erratics of, 220, 226.
Hairmyres Shales, 119.
Halfwayhouse, 231.
Hallhill, 85, 226.
Hallside, 99, 100, 104, 106, 107, 206.
Hamilton, 1, 94, 105, 106.
—— Hill, 223, 224, 236; *see also* Hamiltonhill.
—— Palace Colliery, 164.
Hamiltonhill Colliery, 58, 59, 60.
Hancock, W. C., 89, 90.
Harelaw, 21.
—— Aqueduct, 22.
Harker, A., 180, 182.
Harrison, J. V., 135, 175, 177, 182.
Hatch, F. H., 166, 173, 174, 177, 179, 182, 183, 185.
Haugh Blackband, 63, 65.
Haughhead, 101, 102, 104, 105, 106, 107.
Haughrigg Coal, 61, 63, 65-67, 154, 155, 194.
Hawkhead, 3, 21.
—— Burn, 22.
—— Reservoir, 121.
Hayston, 153.
Heatheryknowe, 111, 115, 116.
—— House, 234.
Heathfield, 83, 86-87; analysis of fire-clay from, 89-90.
Heddle, M. F., 141, 190.
Hermand Quarry, building-stone from, 257, 265.
Hett Dyke, 151.
Heulandite, 189, 190.
Hickling, F., 260.
High Blantyre, 1, 106, 211.
—— Carntyne, 161.
—— Craig, 139.
—— Craigton, 140, 148, 176, 189.
Highland rocks, pebbles of, in boulder-clay, 220, 223, 224, 225, 226.
Hillebrand, W. F., 247.
Hillhead, Campsie, 24.
——, Glasgow, 57.
——, Pollokshaws, 203, 255.
Hillhouse basalts, 178, 181; analysis of, 174, 182.
Hillington, 35, 50.
Hind, W., 85, 88, 113, 114, 125, 128, 129, 132, 134.
Hirst Coals, 67, 70, 73, 74, 77, 78.
—— Limestone, 74, *and see* Calmy.
Hogganfield, 160, 162.
—— Loch, 74, 125, 210.
—— Pit, 96.

Holeburn Coal and Limestone, 67, 70, *and see under* Lyoncross.
Holehead, 137.
HOLLAND, P., 173.
Hollybush, 18, 21.
—— Coal, 21, 22, 27.
—— Limestone, 17, 18, 20, 21, 26, 30, 121-122, 132.
—— Sandstone, 21.
HOPKINS, W., 221.
HORNE, J., 14, 18, 258.
Hosie Limestones, 42 *footnote*. *See also under* Main, Mid, Second *and* Top Hosie.
—— Sandstone, 34, 38, 40, 43, 45, 46, 216.
—— Sill, 162, 163.
Househill, 36, 38.
—— Claybands, 34, 37, 40, 42.
Househillmuir, 38, 212.
HOWE, J. A., 132.
Howwood, 16, 31, 37.
HULL, E., 215.
Humbie Quarry, building-stone from, 257, 265.
Humph Coal, 96, 97, 98, 99, 103, 108, 115, 256.
Huntershill Cement Limestone, 67, 73.
—— Quarries, 72, 73, 76, 253-254, 262, 265; analysis of sandstone from, 264.
Hunterston, 156.
Hurlet Coal, 16, 17, 29, 32, 34, 35, 36-37, 39, 40, 44, 159, 212.
—— district, 15, 16, 17, 18-22, 35-39, 202, 244, 246.
—— Limestone, 15, 16, 17, 29, 32, 34, 35-36, 39, 40, 41, 44, 121, 123, 159, 208, 212; analyses of, 41, 243, 245; classification of, 249.
—— Seam (Limestone and Coal, *q.v.*), 17, 18, 25, 29, 32, 34, 35, 36, 192; as datum-line, 14-15, 32.
—— Sill, 159, 162, 163, 201, 212. *See also*, 36.
HURLL, P. AND M., LTD., 86.
HUXLEY, T. H., 130.

I

Ibrox, 50, 51, 52.
—— Blackband, 49, 51.
IDDINGS, J. P., 183.
Igneous rocks, 135-164; petrology of, 164-190.
Ijolite, 175; analysis of, 174.
Illinois, Coal Measures of, 88.
Inchbelly, 194, 234.
Inchbreck, 234.
Inchnock, dolerite at, 87.
—— Mine, analysis of fireclay from, 89-90.
Inchterf, 153.
Index Limestone, 32, 67, 68-69, 70, 72, 76, 77, 78, 121, 194, 203, 212, 243; analysis of, 245; classification of, 249, 250.
Ironstones, analyses of, 50, 65, 112.
——. *See under* Clayband, Blackband.

J

JACK, R. LOGAN, 5, 11, 13, 17, 24, 25, 41, 135, 142, 190, 228, 230, 231.
JAMIESON, T. F., 233.
Jedburgh basalts, 2, 166, 176, 178-180, 181; analysis of, 182; in Campsie Hills, 29, 136, 137, 138, 139, 142, 144, 166, 179; in Cathkin Hills, 141; in Kilpatrick Hills, 139.
Jewel Coal, 53.
JOHNSTON, R., 96.
Johnston Loch, 237.
Johnstone, 43, 48.
—— Clayband, 46, 49, 50, 54, 55, 163.
—— Gap, 219, 241.
—— Shell-bed, 49, 50-51, 54, 55, 62, 63, 123.
JONES, R., 126, 127.
Joppa Sandstone, 253.
Jordanhill Blackbands, 46, 54, 56, 58.
—— post-glacial deposits, 231. *See also* 218-219.
Jubilee Coal, 52, 54, 57, 58, 62.

K

Kankar, 9.
Kaolin, 89, 260, 261, 262. *See also* Figs. 28-30.
Katiethirstie Quarry, 250.
Kayston, 39.
Kelvin, River, 1, 22, 57, 61, 72, 73, 92, 225, 235, 237, 264; pre-glacial valley of, 39, 191, 214, 215, 216, 217, 218, 219, 223, 225, 233, 236; terraces of, 233, 234.
Kelvingrove, 237.
Kelvinside, 57, 232, 253.
KENDALL, P. F., 228, 240.
Kenmuir Colliery, Tollcross, 101, 102.
Kenmuirhill Colliery, Mount Vernon, 101, 102, 103, 105, 107.
Kenmure, Bishopriggs, ironstones worked at, 60.
—— House, 60, 158.
—— Quarry, 159, 254.
—— Rock, 72.
Kennishead, 69, 212.
Kennyhill, 161.
Keratophyres, 168, 178, 181.
Kessington, 219.
KIDSTON, R., 10, 15, 85, 94, 111, 116, 117, 120, 122, 128, 129, 134.
Killearn, 1, 2, 5, 6, 253.
Killermont, 1, 201, 234.
Kilpatrick district, 17, 22-28, 39-40.
Hills, 1, 3, 157, 207, 208; boulder-clay of, 223; petrology of, 167, 176, 178, 181; physical features of, 238; road-metal from, 250; striæ on, 220; structure of, 192; volcanic rocks of, 135, 137, 139-140, 148-149; zeolites of, 188-190.

Kilsyth Cloven Coal, 59, 63, 65, 66.
—— Coking Coal, 46, 51, 55-56, 62, 63-64, 67, 194, 196, 209; analyses of, 64.
—— district, 1, 56, 73, 78, 62-67, 216, 225, 234; dolerite sills and dykes of, 149-152, 153-157, 166, 175, 186-188, *see also* 66-67; faults of, 208-209; road-metal quarries of, 250, 251; sands and gravels of, 264; structure of, *see* 192-198.
Kiltongue Coal, 93, 95, 96, 97, 98, 100, 101, 108, 109, 111-112, 210
—— Musselband, 97, 98, 100, 101-102, 108, 111, 112.
Kingask neck, E. Fife, 151.
Kinkell, 166, 186.
Kirk Burn, 104.
Kirkburn Quarry, 104, 256, 258, 262; microslide of sandstone from, 263.
KIRKBY, J. W., 126.
Kirkintilloch district, 62-67, 77-79, 92, 154, 209, 216, 233, 234, 267; structure of, *see* 192-198.
Kirkwood Colliery, 109, 112, 115.
Kittoch Mill, 142.
Knightswood, 48, 53, 55, 56, 58, 59, 61, 163, 231.
—— Gas Coal, 52, 54, 58, 62, 253.
—— Main Coal, 59, 61.
—— Stone Coal, 54, 58.
Knockmilly, 159.

L

LACROIX, A., 170, 171, 174, 175.
Lady Ann Coal, 18, 21.
Ladygrange Coal, 97, 98, 102, 108, 112-113.
Laigh Netherton, 141.
Laird's Hill, 208.
Lairs Hill, 24, 137, 138, 139, 148, 182, 185, 208.
Lake deposits, glacial, 219, 230.
Lambhill, 58, 220.
Lanarkian Series, 129.
Langmuir, 116.
Langshot, 40.
—— Fault, 26, 42, 208.
Langside, 206.
Largo Law, 151.
Laumontite, 190.
Laurvikite, 184; analysis of, 183.
Lavas. *See* Volcanic rocks.
Law Farm, Garscadden, 27, 159.
Lawmuir, 27.
Leckethill Cottages, 74, 87.
LEE, G. W., 30.
Lennox Castle, 27, 28.
Lennoxtown, 3, 13, 41, 44, 167, 192, 240, 241.
—— Essexite. *See under* Essexite.
Lenzie, 61, 72, 74, 198, 209, 237.
—— -Torphichen dyke, 149, 153, 154, 157, 158.
Lesmahagow, 15, 30.
Lethamhill, 96.
Letterick Colliery, 106.
Levenseat Limestone, 67. *See under* Castlecary.
Levern Water, 20, 38, 246.
Liddisdale Cementstones, 14, 15, 22.
Lillie's Sandstone, 34, 39, 40, 43, 46.
—— Shale-Coal, 34, 38-39, 43.
Limburgites, 178; analysis of, 174, 182.
Limecraigs, 18, 20, 21.
Limestone Coal Group, 3, 14, 32, 34-46, palæontology of, *see* 122-127, 131, 132, 133.
Limestones and Cements, 243-250.
Linlithgow, 88, 149, 188.
Linn House, 160, 203.
Little Auchinback, 69, 246.
—— Bin, 137, 181.
—— Caldon, 142, 178, 182.
—— Corrie, 13, 142, 144, 145, 240, 241.
Liver Rock, Giffnock, 71, 254, 255, 262, analysis of, 264.
Loanend, 211, 212.
Locharbriggs, building-stone from, 257, 262, 265.
Lochend House, 87, 210.
—— Loch, 91, 109, 222, 234.
Lochgreen, 222, 234.
Lochinch Colliery, 52, 53.
Lochs. *See* Antermony, Bardowie, Bishop, Black, Craigallian, Garnqueen, Goil, Hogganfield, Johnston, Katrine, Lochend, Lomond, South, Woodend.
Lochwinnoch, 15.
Lochwood, 111, 112, 113, 222.
Lomond, Loch, 220, 230, 231, 235, 236.
LOTHIAN, A. V., 147, 166, 167, 176, 185, 186.
Loup of Fintry, 240.
Lower Blackband: of Blackhill, 60; of Garscadden, 46, 49, 51, 54, 56; of Gartshore, 64; of Paisley, 51; of Possil, 54, 59, 65.
—— Carboniferous, 10, 125, 128. 131, 132, 134.
—— Coal Measures, 94, 129.
—— Drumgray Coal, 97, 98, 100, 101, 108, 110, 163, 164.
—— Fireclay. *See* Glenboig.
—— Limestone Group, 3, 14, 32, 34-46, 216; palæontology of, *see* 122-127, 131, 132, 133.
—— Old Red Sandstone, 2, 5, 6, 253.
—— Orchard Limestone, 71, 73.
—— Slatyband Ironstone, 86.
Luggie Burn, Coatbridge district, 116, 117.
—— Water, 78, 154, 198, 234.
Lyoncross Coal, 67, 69, 71, 73, 206.
—— Farm, 69.
—— Limestone, 67, 69, 71, 73, 78, 203, 206, 212, 243, 246; analysis of, 245; classification of, 249.

M

MACCONOCHIE, A., 121.
M'CREATH, J., 202.
MACDONALD, D. P., 166, 188.

MacGregor, A. G., 185.
Mackinder, H. J., 235, 239.
M'Lennan, J. S., 56, 58.
Macnair, P., 8, 17, 20, 23, 26, 27, 30, 41, 72, 125, 165, 171, 172; referred to in footnotes, 19, 21, 24, 25, 29, 32, 35, 36, 37, 39, 40, 42, 43, 44, 45, 70, 162, 163.
M'Phail, H., 35, 37, 38, 43.
Main Blackband of Cadder, 54, 59, 60, 61.
—— Coal, 96, 97, 98, 99, 103, 104, 108, 115, 210.
—— ——, Cadder. *See* Cadder.
—— ——, Giffnock, 53.
—— ——, Hurlet. *See* Hurlet Coal.
—— ——, Knightswood and Possil, 54, 59, 62, 65.
—— ——, Meiklehill. *See* Meiklehill.
—— Hosie Limestone, 34, 38, 40, 43, 45, 46.
—— Limestone. *See* Hurlet Limestone.
March Burn, 137.
Markle basalts, 175, 176; in Campsie Hills, 137, 138, 139, 147, 148, 149; in Cathkin Hills, 250; in Kilpatrick Hills, 139, 140, 149; petrology of, 167, 175, 176-177; zeolites in, 189.
Marshall, P., 168.
Maryhill, 53, 55, 56, 57, 61, 210, 225
Maucher Burn, 7.
Mauchline, building-stone from, 257, 258.
Maufe, H. B., 9.
Meadowhead, 113.
Meikle Bin, 136, 142, 147, 148, 166, 183, 185, 192, 228, 238.
—— Caldon, 142.
Meiklehill, 63, 64, 65, 78.
—— Main Coal, 61, 62, 63, 65, 66.
—— Wee Coal, 61, 62, 63, 65, 66.
Mid Drumgray Coal, 97.
—— Hosie Limestone, 34, 38, 43, 45, 46.
Middle Coal Measures, 94, 129.
Mill Coal, 93, 101, 109.
—— Farm, 141.
Millburn Beds, 23, 25.
Millersneuk, 158.
Millerston, 86, 112, 222, 266.
Millstone Grit, 2, 3, 10, 32, 75, 79, 80-92, 93, 98, 191, 192, 194, 198, 210, 255-256; palæontology of, 120, 127-128, 131, 134.
Milncroft, 160, 236.
—— Quarry, 161, 162.
Milndavie, 140.
Milngavie district, 3, 17, 22, 39, 78, 190, 209, 238, 266; structure of, 192.
—— Sills, 149, 159-160, 175.
Milton (of Campsie), 3, 32, 40, 78, 125, 126, 157, 192, 208.
Molendinar Burn, 160.
Mollinburn, 150, 154, 158, 222, 237.
Monzonites, 184.
Moodiesburn, 74, 159.
"Moor Rock," 71, 254, 255, 264.
—— —— Coal, 71.
Moraines, 228.
Mort, F., 160, 165.
Mossdale Coal, 99, *and see under* Upper.
Mosshead, 40.
Motherwell, 94.
Moulding sand, 85, 87, 255, 256, 259, 260, 261, 263.
Mount Hooly, 43.
—— Florida, 211.
—— Vernon, 96, 110, 111, 113, 115, 227, 266.
—— —— Fault, 3, *and see under* Shettleston.
Muckcroft, 237.
Mugdock, 159, 160, 192, 266.
Mugearites, 166, 167, 178, 180-181; analyses of, 182; in Campsie Hills, 137, 138, 139; in Cathkin Hills, 142; in Kilpatrick Hills, 139, 140.
Muir, 141, 202.
Muirhead, Campsie, 24, 27, 42, 43.
—— Glenboig, 74.
Muirhouses, 232.
Muirside, 226.
Murrayshall Limestone, 30.
Musselband Coal and Ironstone, 97, 98, 102, 108, 112, 113, 114.
Mutton Pit, 113.
Myremailing, 77, 158, 237.

N

Naismith, T., 172.
Nansen, F., 215.
Natrolite, 190.
Nebraska, Coal Measures of, 88. *See also* 128.
Necropolis sill, 160-161, 172, 173, 236, 251.
Neilson, J., 14, 42, 43, 70, 83, 84, 95, 115, 124, 125, 126, 127, 130, 133, 233.
—— Shell-bed, 26, 34, 38, 42-43, 45.
Neilston Blackband, 63, 64-65, 154.
—— House Coal, 63.
—— Smithy Coal, 63.
Nepheline, 168; in essexite, 165, 168, 169, 170, 171; in phonolite, 167, 168, 184, 185; in theralite, 165, 168, 174.
—— -basalts, 178, 181; analysis of, 174, 182.
—— -teschenites, 160, 165, 168, 171-172, 173; analysis of, 170.
Nethercraigs, 18, 22.
Nethercroy, 64, 154, 157, 196, 208, 209.
—— -Dullatur Fault, 154, 155, 196, 208-209.
Netherinch, 234.
Netherton, Garscube, 254.
"New Red" Sandstone, building-stones from, 257, 258, 262.
New Swinton Pit, 86.
Newlands, Baillieston, 116, 117, 163, 164.
—— Campsie, 40, 43.
Newton Coal, 18, 22.
—— Colliery, 101, 102, 164.
—— o' Fintry, 148, 184, 228.
Niethammer, G., 168.

Nimmo and Co., Ltd., Messrs J., 92.
Nine-inch Coal, 52.
Nitshill, 36, 37, 39, 50, 51, 52, 53, 237, 243, 266; railway cutting at, 67, 68, 69.
—— Sandstone, 52-53, 59, 253.
North Bardowie, 40, 159.
—— Blochairn, 24.
—— Brae Coal, 70.
—— —— of Campsie, 22, 24, 34, 40-44.
—— Brediland, 21.
—— Calder Water, 116, 117, 118, 130, 163, 218, 222, 233, 235, 237.
—— Cardonald, 163.
—— Mount Vernon, 114.

O

Oak, in peat, 234.
Ochil Fault, 6.
Oil-Shale Group, 14, 15, 17, 22.
Old Crookston, 19, 36, 162.
—— Jordanhill Blackband, 58.
—— Kilpatrick, 225.
—— Red Sandstone, 2, 5-9, 13, 136, 208, 253.
Oldbarhills, 21.
Olivine-dolerite dykes, Baillieston district, 2, 149, 152, 163-164, 213.
—— —— Sills. *See* Teschenite.
Orbiston House, 107.
Orchard, 52, 70, 71, 246.
—— Limestone, 67, 69, 71, 72, 73, 77, 78, 122, 203, 243, 246; analysis of, 246.
—— Quarry, 161, 251.
Orion Pit, 106.
Ormiston and Sons, Messrs J. W., 112.
Over Possil, 58.
Overlee, 203.
—— Viaduct, 69, 212.
Overwood Quarry, Stonehouse, 257, 265.

P

Paisley, 16, 26, 27, 31, 34, 48, 215, 217, 222, 231, 241.
—— (East) and Hurlet district, 16, 18-22, 35-39.
—— teschenite sills, 149, 162-163, 173-174.
Palacecraig, 118.
—— Ironstone, 106, 117, 130.
Palæontology, 119-134.
Parkhead, 211, 224, 232.
Parkhouse Fault, 36, 212.
Partick, 57, 217, 266.
Paterson and Sons, Messrs, 75, 81.
Patton, A., 127.
Peach, A. M., 222.
—— B. N., 8, 14, 44, 127, 150, 226.
Pearce, F., 168.
Peasweep Pit, 114, 115.
Peat, 234.
Penney, F., 246.
Peppercraig trachyte, 184; analysis of, 183.
Permian sandstones, 257, 258, 262.
Permo-Carboniferous, igneous rocks assigned to, 2, 151, 152.
Phonolite, 148, 167, 168, 184-185; analyses of, 184.
Physical Features, 1, 235-242.
Picrite of Blackburn, Lothian, analysis quoted, 174.
Pinus sylvestris, roots of, in peat, 234.
Player, J. H., 174, 182.
Plean Limestones, 74, 79.
—— Quarries, 257, 265.
Pleistocene and Recent, 214-234.
Pollard, W., 170, 174, 182.
Pollok House, 52.
—— Pit, 37, 38, 39.
Pollokshaws, 3, 48, 50, 52, 202, 203, 206, 266; sections at, 49, 68; striæ near, 222.
Pollokshields, 3, 51, 203, 211.
Polmadie brick-clays, 231, 232.
Polmaise Quarry, 257.
Polton, 88.
Portland Cement, 246, 249.
—— Oolite, used in buildings, 258, 266.
Posidonomya becheri, 25, 43, 45.
—— *corrugata*, 39, 41, 44, 46, 62, 84.
Possil, 48, 53, 58, 59, 61, 62, 65, 220.
—— Blackbands, 46, 54, 59, 60, 61, 62, 65, 159.
—— Main Coal, 54, 59, 62, 65.
—— Subgroup, 32, 46, 51-53, 57-61, 62, 64.
—— Upper Coal, 54, 59, 60, 61, 62.
Possilpark, 61.
Post-glacial terraces, deposits of, 230-233.
Praeger, R. L., 233.
Pre-glacial topography, 214, 215-218.
Prehnite, 189, 190.
Prince Albert Pit, 35, 40, 55.
Productive Coal Measures, 2, 3, 10, 93-118 *passim*, 191, 198, 203, 206, 210, 216; base of, 81, 85, 86, 91, 92, 93, 98, 100, 109; building-stones from, 256, 257; palæontology of, *see* 120, 128-131; upper limit of, 93-94.
Productus giganteus Limestone, 23, 30.
Provanmill, 74, 95, 161, 224, 244.
—— Road Quarry, 95, 109, 251.
Prudham Quarry, Northumberland, building-stone from, 257, 266.
Purdie and Murray, Ltd., Messrs, 264.
Pyotshaw Coal, 99, 104, 108, 115, 116.

Q

Quarrelton Thick Coal, 22.
Quarry Coal, 49, 52. *See also* Lyoncross Coal.
Quarter, Hamilton, 130.

Quartz-dolerite, analysis of, 188 ; composition diagram of, 187.

—— —— dykes and sills, age of, 149-151, 152, 155-156, 157, 213 ; effect on coals, 66, 67 ; field-relations, *see especially* 153-159 ; petrology of, 165-166, 167, 186-188 ; road-metal quarries in, 157, 158, 159, 251.

Queen's Dock, 217.

Queenslie Colliery, 112, 113, 114.

Queenzie Pit, 63.

Queenzieburn, 78, 154, 194, 208.

—— Fault, 62, 63, 78, 157, 192, 194, 196, 208, 209.

Queenziemill Quarry, 78, 254, 261.

R

Radical Coal, 49, 52.

Radiolarian chert, erratics of, 220, 226.

Radley, E. G., analyses by, 90, 167, 170, 171, 172, 174, 175, 177, 182, 183, 184, 185.

Raes Wood, Hurlet, 36.

Raised Beaches, 215, 230-233.

Ralston, 163.

Ramsay, Sir A. C., 8.

Ratho Sill, referred to, 166.

Ravenscraig, Bathgate Hills, 150.

Red Boulder-clay, 223, 224, 225, 226.

—— Burn, 24.

—— clays of post-glacial age, 218, 219.

—— Measures. *See under* Barren.

Redside, E. Lothian, analysis of basalt from, quoted, 177.

Refractory sandstones, 87, 256, 258, 259 ; microslide of, 263 ; *see also* Moulding sand.

Renfrew, 21, 48, 201, 216, 217, 266.

—— Bank, The, 215, 216, 217.

Renfrewshire Hills, 1, 135, 219, 237

—— Poorhouses, section at, 19, 36.

Reservoirs, 266, 267.

Richey, J. E., 15, 43.

Riddrie, 95, 96, 110, 236.

—— Park, 96, 111, 198.

Riebeckite granite, Ailsa Craig, used for setts, 252.

'Riggin' anticline, Kilsyth, 62, 66, 153, 154, 155, 156, 157, 194, 196, 198, 208, 209, 213 ; sections across, 195, 197.

Riskend, 209.

Rivers, 235. *See under* Avon, Black Cart, Blane Water, Carron, Clyde, Endrick, Forth, Glazert, Gryfe, Kelvin, North Calder, Rotten Calder, South Calder, Tweed, White Cart.

Road-metal, 250-252.

Robertson, D., and H. W. Crosskey, 214, 231.

Robroyston, 46, 53, 55, 61, 73, 122, 210, 246.

—— Limestone, 32, 74, 244, 246 ; analysis of, 245 ; classification of, 249, 250. *See also under* Calmy.

—— Quarry, 74, 224, 244.

Rockvilla, 72, 237.

Roman Cement, The, 75, 81, 82-83, 87, 88, 91, 92.

—— Station, Barrhill, 194 ; Castlehill, 39.

Rosehall Colliery, 101, 104.

Rosenbusch, H., 171, 175 ; analyses quoted from, 170, 174, 183, 184.

Ross Hall Mains, section in White Cart near, 38

Ross of Mull Granite, 258.

Rosshill, 162.

Rotten Calder Water, 1, 107, 218, 235, 237.

Rough Coal, 49, 53.

Rouken Glen, section in, 71-72.

Ruchazie, 111, 198.

Ruchill, 210.

Rutherglen district, 3, 119, 211, 222, 266 ; Coal Measures of, 93, 94, 96-99, 104 ; Millstone Grit of, 80, 81.

Rutley, F., 173.

Rylees, 35. 39.

S

St. Flanan, 48, 63, 68, 78, 157.

—— —— Colliery, 63, 79, 155, 209.

—— —— Fault, 66, 78, 154, 155, 156, 194, 196, 198, 209.

St. Monan's, coral limestones at, 30, 31.

St. Rollox, 198.

Sand, building, 256, 264 ; moulding, *see* Moulding.

Sandholes Coal, 18, 22.

Sands and Gravels, 2, 227-228, 230, 231, 232, 233 ; intercalated with boulder-clay, 218, 219, 220, 223, 225, 226

Sandstone. *See* Building-stone.

Sanguinolites abdenensis, 30, 41.

Sanquhar, Skipsey's Marine Band at, 94.

Saponite, 141.

Saracen Colliery, 58, 59.

Satturland Coal, 52, 253.

Saucel Hill, Paisley, 21.

Saughs, 75.

Schröder, H., 227.

Sclutty Coal, 49, 53.

Scots fir, roots of, in peat, 234.

Scotstoun, 211, 216, 266.

Scott, A., 170 ; analysis by, quoted, 177.

Sculliongour, 41, 169, 244 ; analysis of limestone from, 245 ; classification of limestone from, 249.

Sears, J. H., 171.

Second Hosie Limestone, 34, 39, 43. 45, 46.

—— Ironstone Coal, 49, 52.

Seedhill clay-pit, 231.

Setts, 250-252.

Shale Coal, 54, 58, 59, 62 ; dyke cutting, 158, 159.

Shawlands, 53, 237.

Shearer Graving Dock, section at, 225.

Shettleston district, 3, 162, 266; boulder-clay of, 220; Coal Measures of, 108-118; Millstone Grit of, 85, 86, 95; quarries in, 250, 256; structure of, 198, 206.
—— Fault, 116, 206, 213, 210-211.
Shieldhall, 21, 34, 36, 212.
—— Co-operative Works, bore at, 163.
Shields, Campsie, 35, 43.
—— Bed, 34, 37, 41, 42, 44, 45, 126.
—— Burn, sections in, 41, 42, 43-44, 45.
—— Cottage, 40, 41, 43, 126.
Shiels, Renfrew, 163.
Shirva, 78, 79, 153, 154.
—— Coals, 67, 70, 78-79.
—— Syncline, 92, 194, 196.
Shoshonite, 183.
Shotts Gas Coal, 101.
Sills. *See under* Milngavie, Quartz-dolerite, Teschenite.
Skaterigg Colliery, 56, 58, 59.
Skipsey, R. W., 129, 141; *and* following item.
Skipsey's Marine Band, 93-94, 97, 99, 100, 107, 108, 116, 118, 130, 256.
Slamannan, 82, 101.
Slaty Coal, 49, 53.
Slatyband Ironstone, 283. *See under* Crofthead *and* Lower.
Sloughneagh Burn, 24, 40, 41, 42, 43.
Smelck, L., 170, 177.
Smellie, W. R., 107, 182, 257.
Smith, James, 214.
Smith, John, 38, 123, 130.
Smith, S., 264.
Smithy Coal, Cowglen, 49, 53; Shirva, 79.
Smithy Croft, 95.
Snab, 40.
Solsgirth, 64, 194, 198, 209.
Sommerville, J., 225.
Sourmilk Coal, 96, 100, 114; *see also under* Virgin.
South Brae (or Hill) of Campsie, 22, 24, 25, 26, 40, 41, 42, 43, 44, 157, 192; sections across, 193.
South Calder Water, 107, 235.
South Cardonald, 163.
South Craigend, 24, 25, 26.
South Crosshill, 77.
South Drum, Bonnybridge district, Millstone Grit at, 82.
South Loch, 74, 158.
South Mains, 55.
Southern Uplands, erratics from, 220, 226.
Spencer, J. W., 215.
Spirorbis, 19, 21, 24, 129.
Spittal, 225, 237.
Splint Coal, 96, 97, 98, 103, 108, 114-115, 161, 162, 164, 198.
—— —— of Titwood, 52.
Spout of Ballagan, 11, 120, 244.
—— — —— Sandstone, 11, 12, 13, 136, 138, 144, 145.
—— — Ballochleam, 240.
Springburn, 53, 55, 57, 58, 59, 60, 61, 220, 222, 224, 237; section of Upper Limestone Group at, 68.
Springfield bore, Tollcross, 110.
—— Glen, 67, 69, 70.
Springhill, Baillieston, 115, 116, 226.
Stau-moränen, 227.
Stenhouse, A., 152.
Steps, 75, 80, 234.
Stewart, Capt. J., 71, 203, 206.
Stilbite, 189, 190.
Stinking Coal, 49, 53,
Stirling Sill, 149, 166.
Stone Coal, 49, 52, 253.
—— —— of Knightswood, 54, 59.
Stonelaw, 99, 211.
Stoneree Burn, 64.
Strathaven, 14, 15.
Strathblane, 2, 11, 139, 144, 207, 250, 253, 266.
—— Haugh, 230, 241.
—— Valley, 7, 156, 222, 240. *See also* Blane Valley.
Strathbungo, 203.
Striæ, glacial, 220-222.
Strone, 35, 64, 157, 194.
Summerston, 60, 234.
Sutherland, J. R., 267.

T

Tait, D., 31, 84, 88, 120, 121, 125, 128.
Tamshill, 58.
Tannochside Colliery, 101, 102, 104, 106, 107.
Tarfin, core at, 16, 27.
Tatlock and Thomson, Messrs R. R., 264.
Teall, [Sir] J. J. H., 149, 150, 151, 165, 166, 169, 172, 173, 180, 181, 188.
Termier, P., 168.
Terraces, post-glacial, 230-233; river, 233-234.
Tertiary Period, 215, 216; igneous rocks referred to, 149, 150, 151, 152, 163-164, 186, 211, 213.
Teschenite sills, 2, 149; age of, 151-152, 213; analysis of, 170; of Cathcart, 160, 165, 168, 171-172, 203; of Glasgow, 108, 160-162, 172-173, 210, 236; of Paisley, 162-163, 173-174, 212; road-metal from, 250.
Theralite, 162-163, 165, 168, 174-175; analysis of, 174.
Thirty-inch Coal, 59.
Tholeiites, 186.
Thomas, H. H., 187, 188.
Thomson, J., 123.
Thomsonite, 190.
Thorneycroft, W., 112.
Thornliebank, 50, 70, 71, 72, 125, 203, 222, 266.
Thorntonhall, 16, 36, 42, 202.
Threestonehill, 110, 112, 162.
Tillysow, 37, 38, 120, 121.
Tinto felsite, erratics of, 220, 226.
Titwood bore, 35, 36, 39, 50.
—— Gas Coal, 49, 52.
Tollcross, 96, 110, 112, 113, 114, 115, 116, 218, 227, 266.

Top Hosie Limestone, 32, 34, 39, 40, 44, 45, 46, 50, 62, 63, 246.
Topography. *See under* Physical Features.
——, pre-glacial. *See under* Pre-glacial.
Torphichen-Lenzie dyke, 149, 153, 154, 157, 158.
Torrance, 72, 78, 153, 194, 264.
Torwood Glen, Plean, 88.
Townhead, Barrhead, 21.
—— Reservoir, Kilsyth, 156, 194, 196.
Trachyandesites, 142, 147, 182, 184; analysis of, 183.
Trachybasalts, 142, 147, 177, 182, 183, 184.
Trachytes, 142, 147, 148, 167, 185; analysis of, 183.
Traprain Law, 184, 185.
Traquair, R. H., 10, 127, 130, 134.
Triassic sandstones, 257, 258.
Turnlaw Reservoir, 267.
Twechar, 48, 62, 63, 64, 65, 68, 153, 154, 155, 157, 194, 196; general sections at, 63, 68.
—— Blackbands, 46, 63, 65.
Tweed, River, 235.
Twenty-four-inch Coal, 253.
Two-feet Coal, 49, 52, 59.
Tyrrell, G. W., 149, 150, 152, 159, 165, 166, 175, 177, 186, 188.

U

Uddingston district, 1, 3, 94, 191; Coal Measures of, *see* 99-108; structure of, 206.
“ Under Kiltongue ” Coal, 101, 110.
Understone, 60.
Upper Carboniferous, 10, 125, 128, 130, 134.
—— Carlstoun, 26.
—— Coal, 93, 94, 96, 97, 98, 99, 106, 107, 108, 116, 117, 118, 211, 256.
—— —— of Meiklehill, 78.
—— Drumgray Coal, 97, 100, 101, 108, 110-111.
—— Ell Coal. *See* p. 116.
—— Garscadden Blackband, 46, 51, 54, 56, 216.
—— Ironstone, Gartshore, 64.
—— —— Coal, Cowglen, 52.
—— Limestone Group, 3, 32, 49, 67-79; palæontology of, *see* pp. 122-127, 131, 132, 133; sandstones in, 253-255, 257.
—— Old Red Sandstone, 2, 5, 6-9, 11, 13, 136, 138, 142, 144, 191, 207, 223, 253, 257.
—— Orchard Limestone, 71, 73.
—— Possil Coal, 54, 59, 60, 61, 62.
—— —— Ironstone, 54, 58, 59, 60, 61, 62, 159.
—— Sedimentary Group, Calciferous Sandstone Series, 14-31, 34, 120-122; overlap at base of, 17.
Ure, D., 105, 119, 141.

V

Vaughan, A., 132, 133.
Vents of Campsie Fells, 2, 142-147.
Victoria Park, Whiteinch, fossil forest at, 122, 163.
—— Pit, Nitshill, 35, 39, 50.
Viewpark, 104, 105, 106, 107.
Virgin Coal, 96, 97, 100, 103, 108, 114, 164, 198, 210.
Virtuewell Coal, 97, 98, 100, 102, 108, 113, 130, 257.
Visean, 84, 132, 133.
Volcanic rocks, 2, 3, 13-14, 135-149; petrology of, 166, 167, 175-185; zeolites in, 188-190.

W

Waagen, W., 84.
Wahnschiffe, H., 227.
Walkinshaw, 50.
Wallace, W., 243, 262, 264.
—— Mrs. I. F., 150, 151.
Wandering Coal, 99. *See* Upper Coal.
Wants, 98, 115.
Wardhill, 69, 243.
Wardhouse Burn, 22.
Water Supply, 266-267.
Waterhead, 147.
Watts, W. W., 166, 177, 179.
Waulkmill Glen, 67, 69, 70, 125, 244, 246.
Wee Coal, Garscube, 59, 61.
—— —— Meiklehill, 61, 62, 63, 65, 66.
—— —— Twechar, 63.
—— Stone, Blackhill, 60.
—— —— Cloberhill, 59.
Wellpark Brewery, bore at, 75, 267.
Wells, 267.
Wemyss Bay, building-stone from, 257, 265.
West, Rutherglen, 99.
—— Board, 154, 194, 198, 209.
—— Castleton, 141.
Westbrookhall, 21.
Westburn Colliery, 106.
Wester Gartshore, 153.
—— —— Colliery, 63, 64, 65.
Westerhouse, 210.
Westfield, 60.
Westhills, 141, 250.
Westhorn Water Works, 267.
Westphalian Series, 129.
Westside, 29, 44.
Wham Glen, 46.
Whin, 283.
Whin Sill, 150, 151, 166, 188.
Whinhill Quarry, 36.
Whistleberry, 102, 103, 105.
White Cart, River, 19, 37, 38, 52, 69, 160, 162, 203, 206, 212, 232, 234, 235, 244, 266.
—— Coral Limestone, 30, 244; analysis of, 245, *and see* 249.
—— (Baldernock, *q.v.*) Limestone, 18, 19, 20, 23, 24, 30, 31, 41.
—— Nodular Limestone, 29.
—— trap, 110, 157, 159.

Whiteinch, 233; fossil forest at, 122, 163.
Whitta Sandstones, 8.
Wilderness Plantation, 209, 223.
Wilson, J. S. G. W., 177, 183, 247.
Woodend, Gartcosh, 91, 113.
——, Kilsyth, 208.
—— Loch, 82, 91, 92, 109, 110, 112, 210, 234.
Woodilee, 63, 64, 65, 78.
Woodneuk, 87.
Woodward, H., 127.
Wright, J., 31, 123.
—— W. B., 219.

X

Xenoliths in basalt of Markle type, 147.

Y

Yoker, 55, 211, 225, 266.
Yorkhill, 237.
Young, (Dr.) J., 8, 12, 13, 17 ,22, 24, 25, 26, 28, 29, 40, 42, 43, 44, 45, 71, 73, 74, 76, 120, 122, 123, 126, 127, 141, 163, 169, 224, 234, 243.
—— J. W., 12, 141, 262.
—— (Prof.) J., 76.

Z

Zeolites of Kilpatrick Hills, 189-190.
Zirkel, F., 180.